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ELECTROMECHANICAL components & systems DESIGN 2

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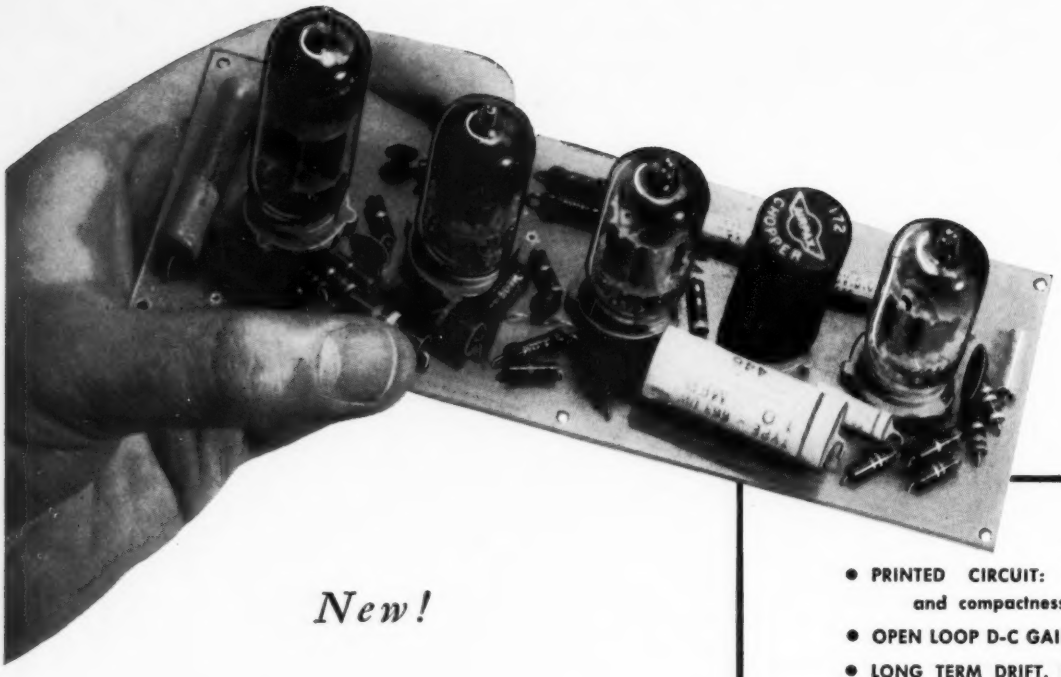

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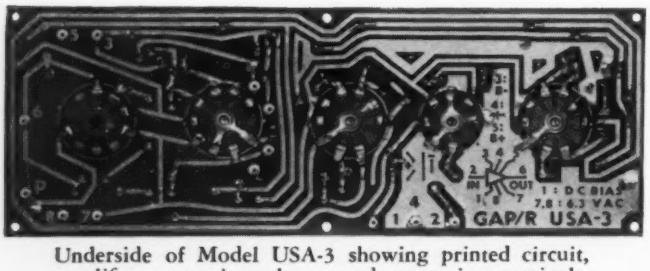
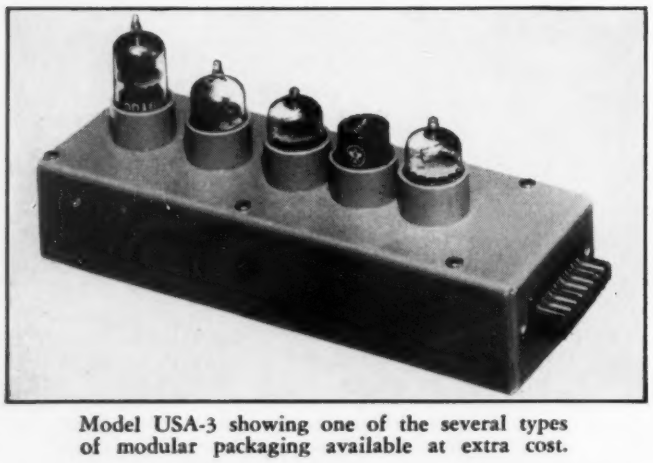


Underside of Model USA-3 showing printed circuit, amplifier connection scheme, and connecting terminals.



Model USA-3 showing one of the several types of modular packaging available at extra cost.

Model USA-3

High performance combined with the reliability and compactness of a printed circuit design are featured in the new Philbrick Universal Stabilized Amplifier, Model USA-3. It is ideally suited for applications to instrumentation, control and analog computation. Extremely high open-loop d-c gain, wide bandwidth, low noise and wide output range are important performance characteristics of this new chopper stabilized amplifier. An interesting design feature makes this instrument safe against self-destruction, even under prolonged overload conditions or direct grounding of its output. At a price of only $95.00, it offers more performance per dollar than any other amplifier on the market today. *Write to George A. Philbrick Researches, Inc., Dept. 19, for Bulletin USA-3.*

GEORGE A.
PHILBRICK
RESEARCHES, INC.
230 Congress Street, Boston 10, Massachusetts

FOR MORE INFORMATION CIRCLE 1 ON INQUIRY CARD

VOLUME 1 • NUMBER 2

NOVEMBER-DECEMBER 1957

ELECTROMECHANICAL

components & systems | DESIGN

COMPONENTS DESIGN

SYSTEMS OF COMPONENTS

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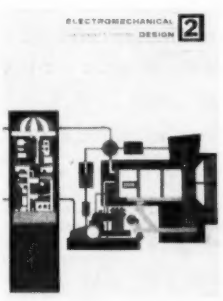
This month's front cover illustrates nothing on the inside pages. Our Art Director, James Flora, was struck with the aesthetics in the electromechanics of a high vacuum setup—and so it became our front cover.



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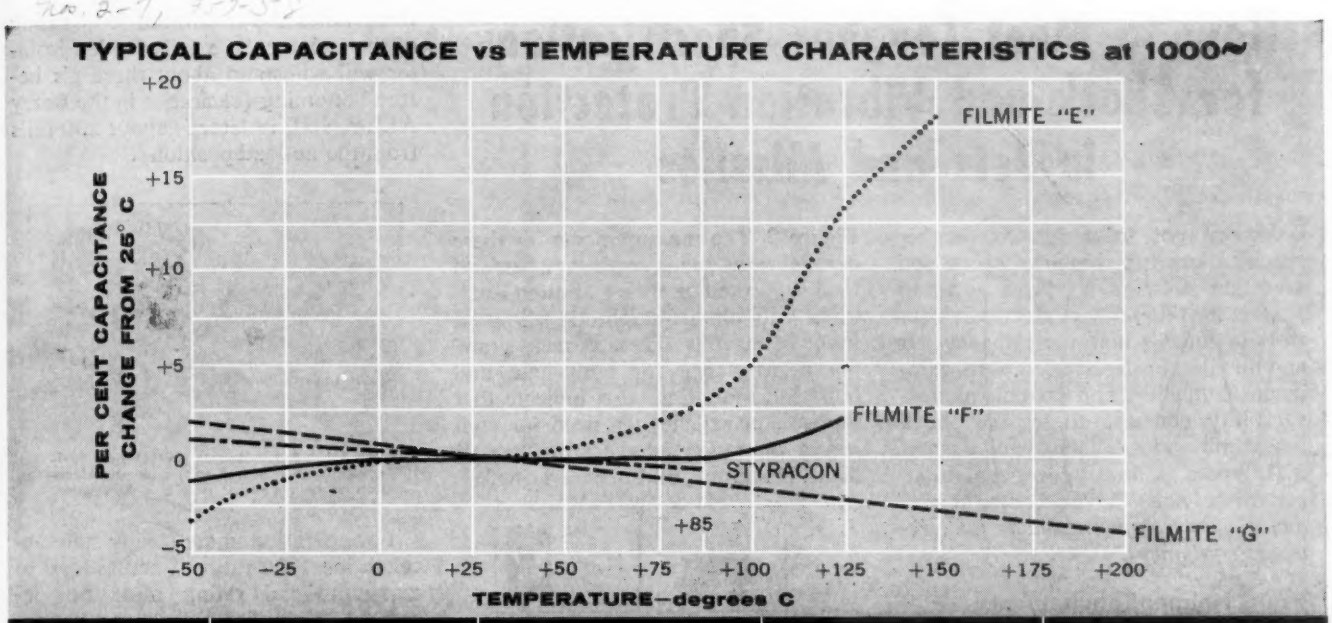

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WRITE FOR TECHNICAL DATA	Engineering Bulletin No. 2510	Engineering Bulletin No. 2410	Engineering Bulletin No. 2560	Engineering Bulletin No. 2610

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FOR MORE INFORMATION CIRCLE 3 ON INQUIRY CARD

How to Meet Tougher Specifications for Shock and Vibration Protection in Jets and Missiles

You've got to design to tougher specifications for combined shock and vibration isolation if you're going to protect the reliability of electronic controls in today's high-performance jets and missiles. Faster accelerations, zero-length launching, and extreme maneuverability combine to impose shock and vibration loads far beyond current MIL specs. *These severe operating conditions must be reduced to a predictable environment suitable for electronic equipment.*

Isolator Requirements

Higher shock inputs require more stiffness in the isolator, to store more energy for a given deflection, so there will be less energy to dissipate if the isolator bottoms. *Higher vibration amplitudes* call for greater clearances and minimum transmissibility at resonance. And vibration protection *under high-g sustained acceleration* demands a combination of these characteristics.

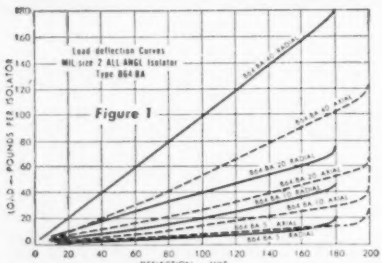


Figure 1

Use of Performance Curves

The characteristics of an isolator having the stiffness necessary for handling the shock and sustained accelerations of jet and missile take-offs is shown by the curves of Figure 1. These curves can be used in choosing the proper isolator for operation under the expected service conditions, since they show both the deflection of isolators under a wide range of loadings and the maximum allowable deflection due to the combination of static load, sustained acceleration, and vibration amplitude.

A transmissibility at resonance well below three — considered exceptionally low — is shown by the curves of Figure 2. The measurements for these curves were made with a 27-pound load supported on four 10-pound isolators, with double-amplitude vibration input of 80 mils. These curves, showing performance for both base and bulkhead mounting, also indicate that the isolator satisfies the need for *consistent operation in every attitude* of flight, launching, and maneuvering.

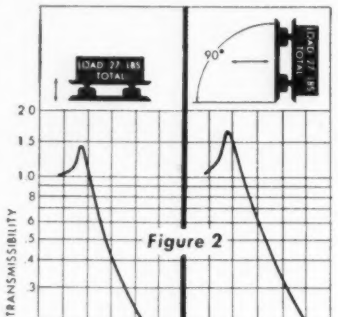
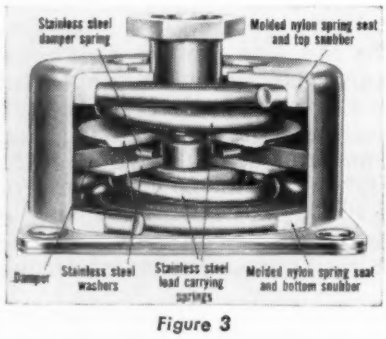


Figure 2

Figure 3 illustrates the construction of the B64 isolator that provides the performance characteristics shown by the curves, yet is dimensionally interchangeable with MIL-size mounts of comparable load ratings.


Stainless steel damper spring
Molded nylon spring seat and top snubber
Damper
Stainless steel washers
Stainless steel load carrying springs
Molded nylon spring seat and bottom snubber
Figure 3

Sustained Acceleration

The following example shows how Figure 1 aids in the choice of an isolator to give vibration protection under sustained acceleration. The straight part of the curves shows that the working range for each isolator allows about 190 mils maximum deflection (for axial loads). This occurs at about three times the maximum load rating of the isolator. So a fully loaded isolator will withstand about three g's before bottoming (clearance in the Barry ALL-ANGL isolator is about 200 mils from the no-load position).

ALL-ANGL Barry Mounts protect vital fuel-gaging-system power units under acceleration of 6 g vertical and 5 g horizontal.

For operation under steady-state accelerations, the ratio of actual load to maximum-load rating must be decreased. Thus, for a 6-g acceleration, a five-pound isolator would bottom at an actual load of 2.5 pounds, or a 40-pound isolator would bottom at an actual load of 20 pounds.

Vibration Protection

Because it is necessary to allow for the deflection due to applied vibration, ALL-ANGL isolators are often used at loads below their maximum ratings. For example: assume a 40-pound isolator loaded at 15 pounds and required to withstand 4 g's. From the curve, the 60-pound force corresponding to 4 g's will produce a 110-mil deflection. Since this is 80 mils below the 190-mil allowable maximum, a double-amplitude vibration input of 80 mils can easily be handled. This is a conservative application which allows for possible resonant conditions.

Because natural frequency increases as the isolator loading decreases, the final choice must take into consideration the relative importance of steady-state loading, vibration isolation, and shock protection. All of these factors are evaluated in engineering data available from Barry Controls Incorporated.

Additional Design Data

Other curves of isolator characteristics, and data on their use in designing *for predictable environment in jets and missiles,* are contained in Barry Bulletin 57-2. This bulletin fully describes the complete line of ALL-ANGL Barrymount isolators in standard MIL sizes. Write today for your free copy.

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Editors Extraordinary

The men listed on our masthead as Staff Columnists, Special Project Editors and Contributing Editors are Editors Extraordinary. They are engineers or scientists who have attained a measure of success and achievement in their professional work. They have functioned as spokesmen for an industry or segment of industry; they have published professional papers; they have chaired professional meetings; they have been and some are now on various committees of professional societies.

These men are our Editors Extraordinary because they are currently earning their livelihood as engineers or scientists in those areas in which they report to you on significant facts, trends or developments. They are united in one common editorial goal: to assist our full time editorial staff in making this publication your sourcebook of ideas and techniques in electromechanical research, development, design and the management of these functions. Their incentive and compensation in these tasks is the gratification of fostering new ideas and new understandings among their colleagues—you, our readers.

Who they are and, briefly, what they have done are on the following pages.

How Did We Get Your Name?

Before the publication of our first issue (September-October), we mailed engineering management in over 8,000 U. S. companies a "Circulation Qualification Form" in which we offered a year's free subscription to a limited number of qualified research, development and design engineers in their plants. If you are now receiving this publication without having made a direct request, your name may have been submitted in this manner.

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Editor and Publisher

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Editors Extraordinary

Staff Columnist

David Bandel
was recently appointed Associate Technical Director of Tracerlab, Inc. Before that time he was manager of the Chemical Research Division and special technical assistant to the Vice President of the Commercial Development Division of the American Machine and Foundry Co. In this capacity he has worked in the field of dielectric materials, glass fibre, plastic films, electrical properties of glass fibre, reinforced tefelon, silicones, high temperature insulation materials, coated foils for high-volumetric-efficiency capacitors, bread machinery and tobacco machinery. He has a B.S. in chemistry from George Washington University, a Masters in Inorganic chemistry from Brooklyn Polytech and a Ph.D. in polymer chemistry with minors in physical chemistry and chemical engineering. Dr. Bandel's main area of editorial contributions will be in chemical problems peculiar to electromechanical design and development engineers. He also reports on new developments presented at various chemical society meeting of direct interest to the electromechanical engineer.

Renato Contini
is Research Coordinator in Bio-Mechanics and Industrial Engineering at N. Y. U.'s College of Engineering. His unclassified work has been in the design of prosthetic devices, turnpike booths, solar energy devies, meteorological instrumentation and medical equipment. In these projects he coordinates research and development among mechanical, electrical and industrial engineers; experimental and clinical psychologists; mathematicians; and other scientists. He has been Vice President in charge of engineering for Hub Industries, Inc., and Chief Engineer for Langley Aircraft Corp. He holds a B.S.M.E. from N. Y. U. Mr. Contini's column on Human Factors in Design appears in each issue.

Jesse Edward Hobson
has been Director of Armour Research Foundation in Chicago, Ill. and more lately Director of Stanford Research Institute in Menlo Park, Cal. He is now vice president of the United Fruit Co. Dr. Hobson holds a Bachelor's and Master's Degree in electrical engineering from Purdue University and a Ph.D. from California Institute of Technology. In 1940 he was the Eta Kappa Nu "Outstanding Electrical Engineer of the U. S." He has functioned as a consultant to a variety of governmental and industrial research organizations and as a member of engineering cmmittees. Dr. Hobson concentrates in the myriad of problems in research and development administration and organization.

Israel Katz
is currently Manager of Liaison and Consulting Engineering at the General Electric Advanced Electronic Center in Ithaca, New York and consulting engineer in the area of advanced weapons systems. Formerly an associate professor of mechanical engineering at Cornell University where he taught for 14 years, he has been a frequent contributor to the classified technical literature, to engineering publications and is the author of *Principles of Aircraft Propulsion Machinery*. Mr. Katz's area of editorial work is in thermodynamics, instrumentation and components and systems in military and non-military applications.

Emile Labin
a French citizen residing in France, is currently President and General Manager of *Automation-Electronique-Recherche Opérationnelle*. Holder of more than 90 patents, he has achieved a number of firsts in the electronic industry. In the early 30's he developed a low-definition wire-television system between Paris and Lyon and in the mid 30's developed the first high-definition television system in France.

In 1941 he joined Federal Telecommunications Laboratories and in 1946 became its technical director in charge of research and development coordination within I.T.T. companies throughout the world. In 1953 he became technical director of Radio Industrie and set up and directed their work on digital computers, hyperfrequency tubes, radar systems and television equipment.

In future issues, Emile Labin's reports will range from French technical developments to management concepts that may be of interest to American engineers.

Ronald C. Vickery
is currently head of the chemistry department at Horizons, Inc. in Cleveland, Ohio. He has a D.Sc. from London University, M.D. from Oxford University, M.Sc. (London), a D.Phil. (Oxon), and a D.Sc. (London) for research in the rare earth field. From 1950 until the beginning of 1954 he was Senior Research Officer, Division of Industrial Chemistry (Commonwealth Scientific and Industrial Research Organization of the Australian government), studying the chemistry of rare earth complexes by spectrophotometric, ion exchange and radioisotopic techniques. He has published over 50 original papers on various aspects of rare earth chemistry and writes about chemical problems peculiar to electromechanical design and development engineers. His current series emphasizes the potential applications of rare earth oxides and metals to components of interest to design and development engineers.

Contributing Editors

Herbert K. Brown
formerly director and dean of the graduate division of the College of Engineering at Northeastern University, is now at AVCO Research Laboratory in Everett, Mass. He studied mechanical engineering as an undergraduate student and then went on to receive a Master's degree from Wayne University in mathematics and a Ph.D. from the University of Michigan in Ann Arbor. He has published a number of papers on the application of mathematics to the solution of engineering problems—the area in which he functions as an editorial contributor.

Harry Donald Conway
has a Bachelor's Degree in mechanical engineering and a Ph.D. and D.Sc. in applied mechanics, all from London University. He has worked as a stress analyst in the aircraft industry, a scientific officer of the engineering division of the National Physical Laboratory in England and has been on the staff as a Professor of Engineering Mechanics and Materials at Cornell University since 1947. He has published over 70 papers in the area of strength of materials, theory of elasticity, stress analysis and vibration analysis. In 1953-1954 he was a Visiting Professor, Imperial College of Science, London University, on a fellowship accorded by the John S. Guggenheim Foundation. His textbooks include *Aircraft Strength of Materials* (Chapman & Hall, London, 1947) and *Mechanics of Materials* (Prentice-Hall, New York, 1950). Dr. Conway contributes in strength of materials, stress analysis and vibration analysis.

Oliver G. Haywood, Jr.
before becoming vice president of Emerson Electric Manufacturing Co. of St. Louis, Mo. and general manager of their Electronics and Avionics Division was manager of Waltham Laboratories of Sylvania Electric Products, Inc. He has a B.S. from the United States Military Academy, an M.S. from Harvard and a D.Sc. from MIT. His last military assignment was with the Air Research and Development Command where he organized and headed the Office of Scientific Research. He has served at Los Alamos Scientific Laboratories and with the Atomic Energy Commission. He has worked in the research, development and production of missile systems, avionics, electronics, fire control systems, air frame structures, computers, rocket launchers, instrumentation and related assemblies of airborne, shipborne and ground based systems. Dr. Haywood is a contributing editor in the technical areas described above and in engineering management.

Herbert Kaizer
holds an A.B., A.M. and Ph.D. from Boston University. Currently he is Manager of IBM's Experimental Psychology Group within the Kingston Military Products Division. He has worked in the development of engineering psychology research programs as applied to SAGE (Semi-Automatic Ground Environment), and has participated in Air Force-sponsored research on projects involving aerial photo-interpretation, aerial reconnaissance and other visual perception problems. He reports on human factors in design from the experimental psychologist's point of view.

George King
is currently chief mechanical engineer at Narmco Resins and Coating Co. in Costa Mesa, Cal. In his professional career he has specialized in the research development and design of special purpose automatic machinery and processes at Sylvania Electric Products Co. Inc., Harvard Engineering Co., and Polaroid Corp. As a contributing editor, Mr. King is currently working on articles dealing with electromechanical aspects of instrument design and high and low speed machinery.

William W. Seifert
currently associate professor in the electrical engineering department of MIT, has a B.E.E. from Renseelaer Polytech and a S.M. and a Sc.D. from MIT in electrical engineering. He has written extensively in the classified literature on analysis of missile control systems, nuclear reactor simulation techniques and various types of servo systems. He has taught special summer programs in analog computation and control systems engineering. As assistant director of the Dynamic Analysis Control Laboratory at MIT, he has worked on studies of weapon systems including torpedo systems, missile systems, conventional aircraft systems. His editorial work will encompass articles on control systems and electromechanical servo components.

Special Projects Editors

Martin E. Kagan
is vice president of Yardney Electric Co., an authority on battery development and design and a specialist in battery powered systems in industrial and military applications. Because of his extensive travel for Yardney Electric and his proficiency with foreign languages, we should create the special category of "roving editor" for him. In our first issue he reported on WESCON developments from California. At present he is on a multi-country tour of Europe and will be returning with a report on several European engineering developments.

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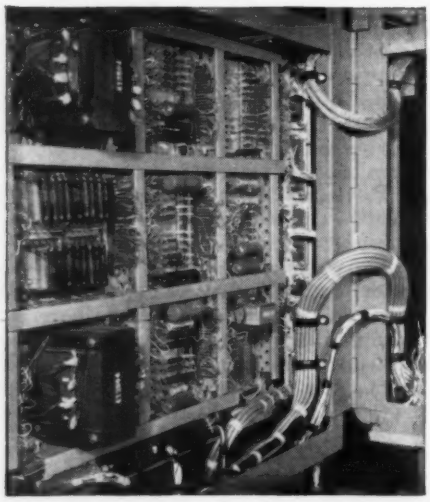

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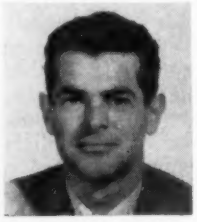
Special Projects Editors

David I. Kosowsky
received his B.E.E. from CCNY and his S.M. and Sc.D. from MIT. He was a staff member of the Research Laboratory of Electronics (MIT) from 1951 to 1955 and was engaged in research on Missile Systems, Applications of Statistical Communication Theory and Filter Theory. He was responsible for the development of techniques for the synthesis and realization of crystal filters. Currently he is Chief Development Engineer of the Filter and Instrument Department at Hycon Eastern and reports on special projects, in his area of specialization.



Saul Padwo
is a member of M. Ten Bosch's Pleasantville, N. Y. engineering management group. He has a degree in electrical engineering from the College of the City of New York and has worked in the missille and aircraft field on component and systems design and development. Mr. Padwo's main area of editorial work is in the field of aircraft instrumentation and the selection of foreign papers for translation that are of interest to electromechanical design and development engineers.

Herbert F. Spirer
as assistant chief engineer at CGS Laboratories in Stamford, Conn., has worked in the design and development of data handling and communication equipment for industry and the government. A graduate of Cornell University's course of engineering physics, he has taught electrical engineering and mechanical engineering at Cornell. He has worked as a development and design engineer at MIT Radiation Lab, Sun Oil Co., Eastman Kodak Co. and the General Electric Co. An out-spoken individual on subjects ranging from the technical to the managerial, Mr. Spirer's first contribution in the next issue will be on the subject of reliability.

Foreign Editor

Andrew R. McAndrew
From 1949 to 1951 he was Foreign Affairs Editor of the Current Digest of the Soviet Press. From 1952 to 1953 he was Associate Director of Project NSF-C-5 (a survey of Russian technical and science translations) for the National Science Foundation in Columbia University. From 1953 to 1954 he was Chief Editor of the National Science Foundation Project C-12, dealing with translation of Soviet physics. He is the autor of a Russian-English glossary of metallurgical terms published by the NSF. He has worked for the National Institute for the Unity of Science, a group composed of university professors throughout the United States, and freelanced on Soviet affairs for United Feature Syndicate, the New York *Herald Tribune*, *Commentary*, and other publications. Throughout World War II he was an officer in the Royal Navy, his tour of duty including 14 months of operation from the Russian Far North. As Foreign Editor his translations of European engineering and scientific developments will be a regular monthly feature.

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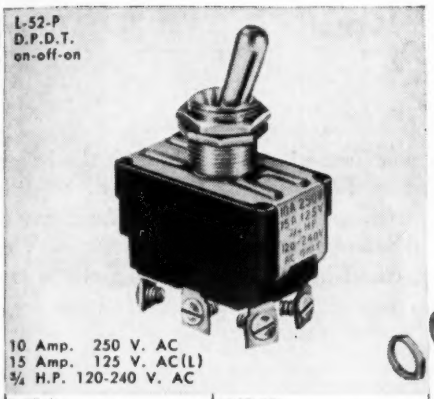

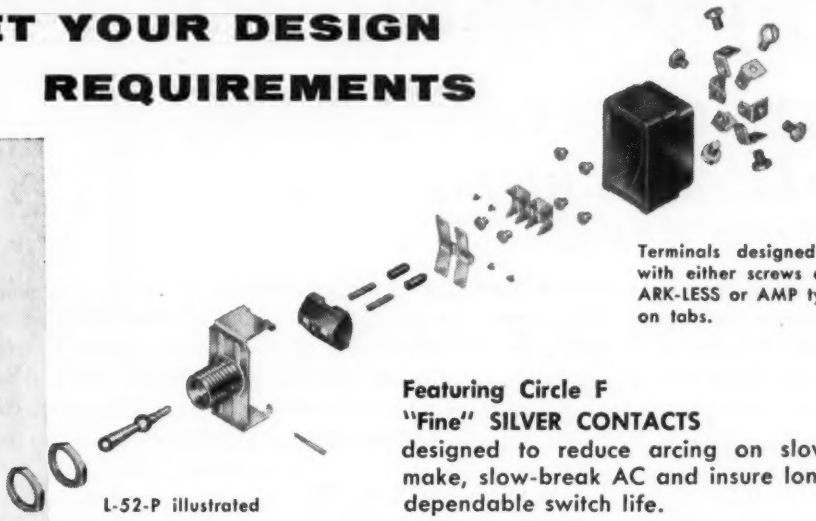

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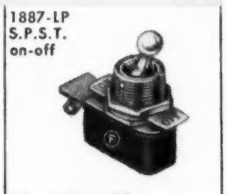

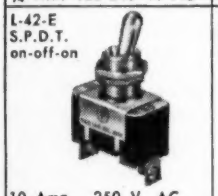

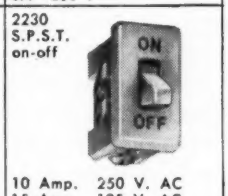

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FOR MORE INFORMATION CIRCLE 6 ON INQUIRY CARD

THE MANIA FOR SECRECY

Andrew R. MacAndrew,
Foreign Editor

Who's Been Hiding What From Whom?

THERE have always been natural limitations to man's communication with man. And, since the ill-fated attempt to build the Tower of Babel, the additional barrier of language has been erected. Now, in our divided world a new obstacle looms up in the most unexpected places to impede contact between searching human intelligences: the mania for secrecy.

It seems that never before has so much zeal been displayed by so many officials to prevent so much material from reaching their own specialists for reasons based on such aberrations of logic.

Without digging too deeply into the historical and anthropological causes of this phenomenon, it seems safe to assume that this caution has been generated by distortion of a quite logical proposition.

The proposition is that the interests of a party engaged in an armaments race are better served if its rival is kept in ignorance of its latest achievements in the technology of destruction. Our assumption is that this axiom was eagerly accepted by patriotic officials who set out lustily to classify documents and their fellow men into secrecy brackets that, like the income brackets, soon came to convey a sort of social prestige at their higher levels. And soon, in the midst of the secrecy-stamping, information-controlling and clearance-issuing *elan,* officials were bound to begin feeling like arbiters of elegance. The elation of power came and with it the urge to extend the range of their competence. And out they went to conquer new acres of paper for the secrecy stamps.

It is probable that many an important military secret has been well guarded from enemy eyes and ears by the zeal of these public servants. But it is at least as certain that much helpful information has also been kept from those who were supposed to provide us with secrets worth keeping: *our own scientists and engineers.*

American scientists, whether engaged in theoretical research or in the application thereof, our engineers, whether working for national defense or not, have a vital stake in keeping abreast of the work in their own fields that is being done abroad. Otherwise, senseless duplication of efforts is bound to occur and cause waste of money and, what is more important, of time. Much can be saved by cashing in on the frequent parallelism in discoveries and inventions by scientists working separately.

Recently, the New York *Herald Tribune* published a report made by Mr. Gerard Piel, the publisher of *Scientific American,* at a session of a Congressional sub-committee. Among other things, Mr. Piel cited five years (1950-1955) spent by "a group of American scientists working in corporations engaged in making computers." They were trying to apply Boolean algebra to the design of computer circuits. Then, five years and $200,000 later, it was discovered that a Soviet engineer named A. G. Lunts had alread solved their problem and described his work in a pape that had appeared in the journal of the USSR Academy o Sciences *(Doklady Akademii Nauk USRR)* in 1950. Thi journal, by the way, could have easily been bought in thi country at that time.

At this point two things come to mind. Either the group should have had a few linguists watching foreig achievements in symbolic logic as applied to computers o this service should have been performed for it by a spe cialized agency, governmental or private.

The fact is that some such agencies did do some trans lating of Russian scientific papers but rather sporadicall and in a perfectly uncoordinated fashion. Now what pre vented this coordination was the above-mentioned secrec mania. Somehow it was considered that we would be o the verge of disaster if the Russians found out which o their own articles were of interest to Americans. Apparentl that would give away something very secret. And as result, translations were stamped secret and kept jealousl not only from private translators but also from other gov ernment departments, so that the same article often ha to be rediscovered and retranslated several times over.

Apparently this zeal for secrecy reached its climax a the beginning of 1952, after which some efforts were made to allow some information on Soviet scientific en deavor to trickle to some not necessarily cleared America scientists, who nevertheless could push Soviet work fur ther for the benefit of this country, at which point, o course, the seal of secrecy would be legitimate. The initia tive was taken by the National Science Foundation whic contracted a Columbia University group to produce non secret translations of Soviet physics papers and to distribut them throughout the country to all American physicist specializing in the particular fields with which the transla tions were concerned.

But, even here, difficulties crept in. The Soviet publica tions to which the group subscribed in Moscow arrive irregularly and with delays. Inquiry revealed that the faul did not lie with the Soviet publishers. Nor were the posta services to blame. The Soviet scientific publications ha reached the American shore all right. In fact, that's where they were. Held up by the U. S. Customs. Why? It wa never easy to understand: maybe some custom officials were diffident about letting into this country articles with such titles as "Study of Electron-Nuclear Showers and Penetrat ing Particles in the Stratosphere at Various Latitudes" o "Analysis of Excited Nuclear Levels by Means of a Shel Model." Especially with all those queer pictures and dia

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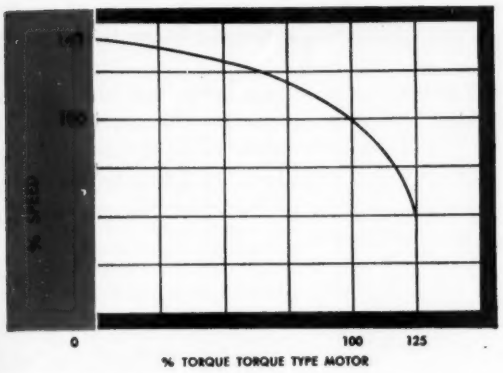
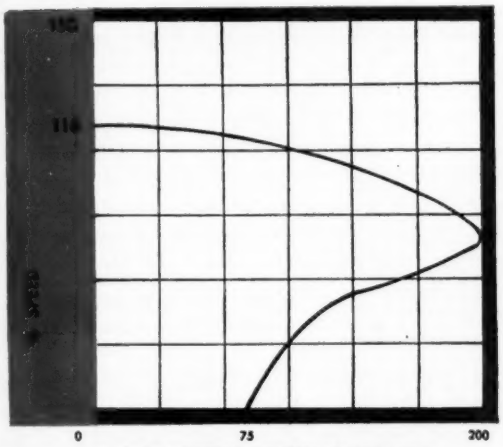


TORQUE TYPE MOTOR

POWER: AC 50 to 60 cycles.

CHARACTERISTICS:

1. No Load speed is determined by number of poles, with a No Load slip of approximately 5%.
2. Full Load speed decreases with an increasing load. Designed to operate at approximately 30% full load slip.
3. No breakdown torque.
4. Starting torque high approximately 125% full load.



INDUCTION CAPACITOR RUN TYPE MOTOR

POWER: AC 50 to 60 cycles.

CHARACTERISTICS:

1. No Load speed is determined by the number of poles, with a no load slip of 2 to 4%.
2. Constant Full Load speed, with a full load slip of approximately 10%.
3. Breakdown torque—approximately 200% full load.
4. Starting torque—approximately 75% full load.

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POWER: AC 50 to 60 cycles.

CHARACTERISTICS:

1. Synchronized speed, determined by number of poles.
2. Starting torque equal to Full Load Torque.
3. Quiet operation.

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CHARACTERISTICS:

1. Synchronized speed, determined by the number of poles.
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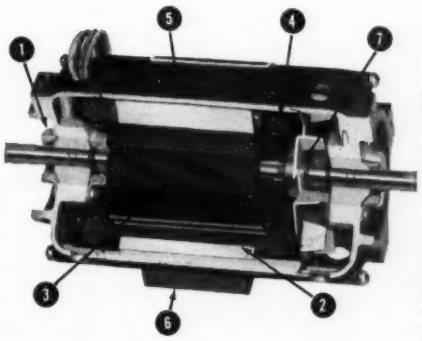
Howard Induction Motors are available in Torque, Induction Capacitor Run, Hysteresis Synchronous and Reluctance Synchronous types. Costs are moderate but depend upon quantity. For full information on Howard Induction Motors, write for bulletin 56A.



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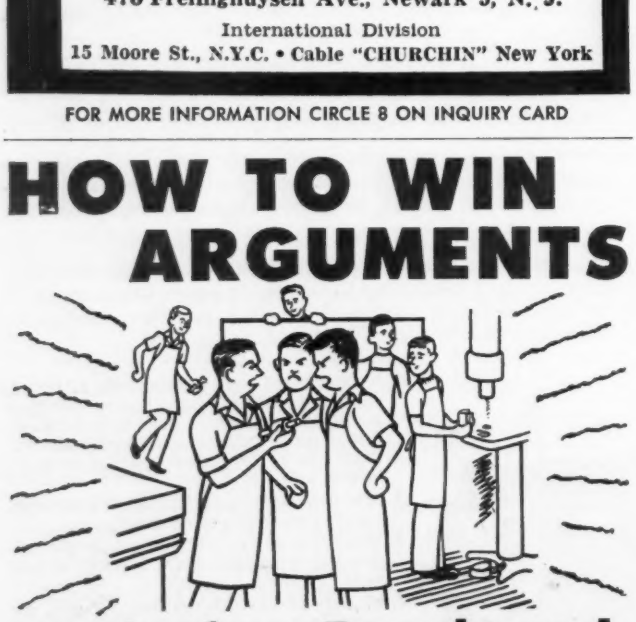

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FOR MORE INFORMATION CIRCLE 9 ON INQUIRY CARD

grams that went with them. They apparently thought such material could easily be subversive stuff, propaganda or something. Others, trying to play it safe, thought that by delaying information it was made harmless. Here, of course, the confusion was merely over the direction the material was going.

Since then, it must be said, things have somewhat calmed down. The country is less zealously guarded against Soviet scientific papers and some English descriptions of these works are more readily available to those interested in them. In this, however, as, alas in a few other things, we are still no match for the Soviets.

According to a source in the Justice Department, the USSR obtains more useful informaion on American research by systematically and perfectly openly following U. S. unclassified publications and translating and distributing every worthwhile paper to their people concerned than they do from spies.

Thus the Soviet publishing house *Mezhdunarodnaya Kniga* (International Books) was reported to have sold, through its New York representative the Four Continents Bookstore, $98,000 worth of Soviet publications in 1956, of which only a small proportion were technical, whereas it bought $316,277 worth of American scientific and technical literature. An idea of the ample use made by Soviet scientists of American and other Western expenditure of money, time and brainpower can be gathered from the footnotes of the very Soviet papers that should be translated. And what is more, it looks as if the Russians think nothing of letting us know what aspects of American research interest them most. We know that practically everything interests them. But what advantages we have derived from this so far remains unclear.

By no means do we imply here that the circulation of American scientific journals should be restricted to authorized persons. We do imply that foreign scientific papers translated for any one particular group of scientists and engineers be made available on a national basis to other scientists and engineers and that there be a freer exchange of scientific and engineering information with our allies.

When President Eisenhower and Prime Minister MacMillan met in Bermuda last spring, the U. S., according to a report in the New York *Times*, declined to give Britain nuclear information on the ground that various American laws required secrecy so that the U. S. could preserve its lead over Russia. That our government now more fully recognizes the importance of communication to scientific accomplishment is evidenced by the President's recent statement that he will ask Congress to relax the laws impeding American sharing of scientific information with our allies. Whether we like it or not, science and engineering, like many other things such as peace, have the tendency to become indivisible.

Starting with our next issue we shall translate for our readers selected information available on Soviet, German, French and other foreign research in fields of interest to them. This selection will be made by specialists familiar with American efforts in the corresponding fields. We invite you to write and let us know what particular type of coverage would be helpful to you; these comments and suggestions will determine our choice for translations in future issues.

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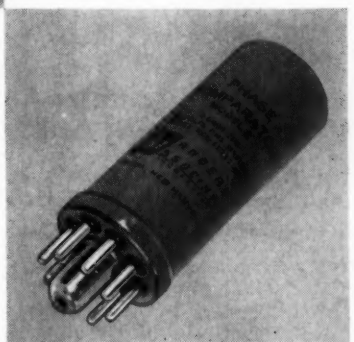

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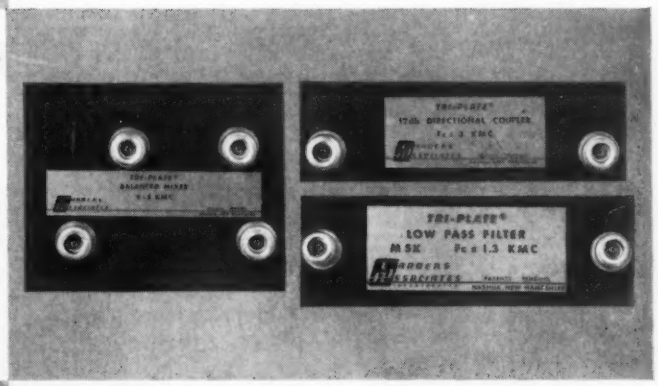

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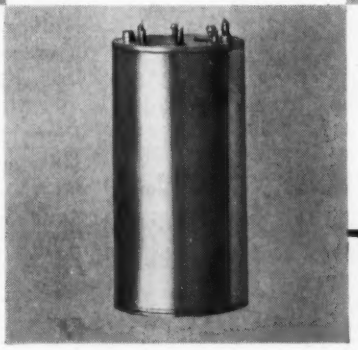

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FOR MORE INFORMATION CIRCLE 10 ON INQUIRY CARD

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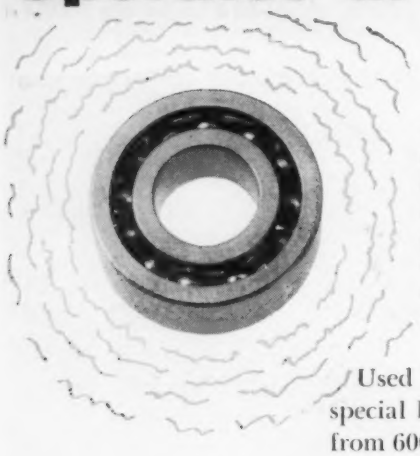

This 7/8"-OD bearing carries a 150-lb. load with a slow oscillatory motion at temperatures to 1100°F. while subjected to vibration and severe corrosion conditions. Other special high-temperature bearings by ITI meet even tougher requirements.

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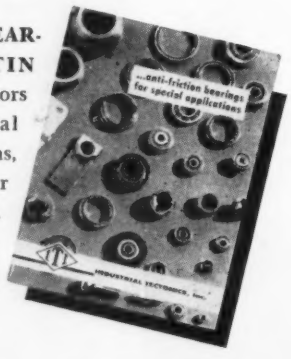

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FOR MORE INFORMATION CIRCLE 11 ON INQUIRY CARD

LETTERS

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Morgan L. Dring, Sr. Proj. Eng.
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Clifton, N. J.

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David Mittman, Eng.
Mechanisms & Computer Lab
Kearfott Company, Inc.

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• • •

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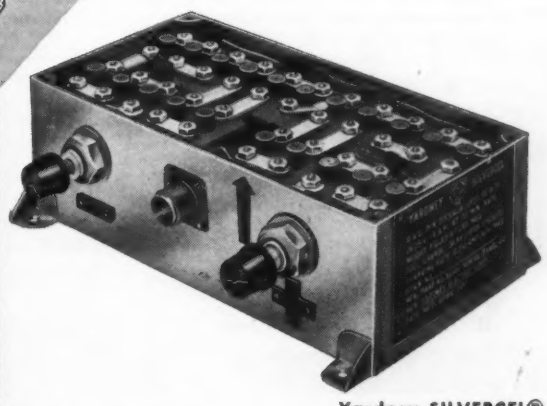

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Yardney Silvercel	Nominal Capacity	Peak Pulse Discharge	Weight (ounces)	H. (all in inches)	W.	D.	Typical Applications
HR 01	0.1 AH	3 amps	0.15	1.38	.67	0.20	Instrumentation
HR 05	0.5 AH	30 amps	0.70	1.52	1.10	0.55	Telemetering
HR 1	1.0 AH	45 amps	0.79	1.98	1.08	0.54	Motor-Driven Recorders
HR 3	3.0 AH	75 amps	2.98	2.86	1.72	0.59	Tow-Target Drones
HR 5	5.0 AH	75 amps	4.24	2.95	2.08	0.80	Photo-Flash, Camera Drives,
HR 10	10 AH	220 amps	7.88	4.78	2.32	0.74	Portable Lights, Missile Guidance
HR 15	15 AH	350 amps	9.70	4.93	2.31	.81	Helicopter Starting
HR 20	20 AH	500 amps	13.82	4.28	2.05	1.73	Missile Power Sources and
HR 21	20 AH	500 amps	15.02	7.56	2.31	0.81	Servo Controls
HR 40	40 AH	600 amps	23.20	7.0	3.25	0.99	Torpedo Propulsion
HR 60	60 AH	1000 amps	31.85	4.50	2.75	2.38	Portable TV
HR 85	100 AH	1900 amps	52.30	9.44	2.81	1.81	Aircraft Power Sources
HR 90	100 AH	1800 amps	51.40	7.0	3.25	2.16	Tow-Target Drones
HR 100	100 AH	2000 amps	44.10	4.78	3.43	2.79	
HR 200	200 AH	3000 amps	102.50	11.31	5.87	1.31	Portable Power Station
HR 300	300 AH	3500 amps	148.00	17.5	4.19	1.78	Portable Power Station

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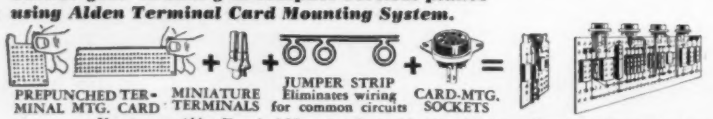

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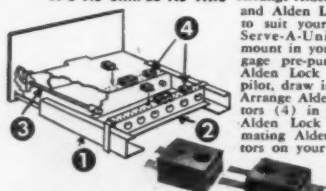

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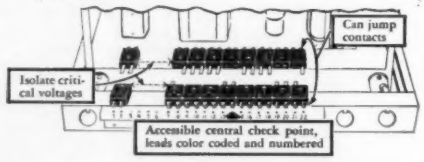

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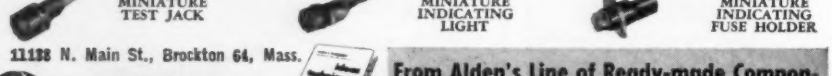

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Self-Aligning Plain Bearings and Rod End Bearings

K. V. HACKMAN

President, Southwest Products Co.
1705 S. Mountain Ave., Dept. EMD 57, Monrovia, Calif.

SOUTHWEST Products Co. manufactures two kinds of self-aligning bearings. (1) The self-aligning plain bearing, as produced by Southwest, consists of only two pieces, a spherical ball with a hole for a close tolerance bolt or shaft to pass through, and a one-piece outer race which completely surrounds the spherical ball. The latter can be mounted anywhere in a housing where self-alignment is required for a bolt or shaft, generally a nonrotating shaft. (2) The self-aligning rod end bearing is the "Monoball®"[1] plain bearing installed in a housing shaped like an eye bolt as the name implies, and in the end of a rod to engage a bolt fastened to a yoke, crevis, or arm. The "Monoball®" self-aligning is not intended for the antifriction purposes of ball or roller bearings supporting *rotating* or rpm shafts. They have many applications in various sizes in aircraft or similar structure, especially a moving structure subject to deflections, twists, vibrations, and strains.

Southwest Products Co. self-aligning plain bearings have distinctive advantages well recognized by the airplane industry, as follows:

1 There are two prominent types (two-piece construction) self-aligning bearings on the market. The Messerschmitt type is by its design the cutting away of metal on one side of the outer race to introduce or load the ball (which weakens the outer race and the accompanying wider tolerance between ball and race) and results in specific costly defects in airplane applications.

2 Southwest "Monoball®" self-aligning bearing has a greater bearing surface, size for size, than any other bearing; therefore, it bears heavier radial and thrust loads, size for size, than any others on the market today.

3 Southwest "Monoball®" self-aligning bearings, due to know-how, can be made of harder and tougher steels SAE 4130, SAE 52100 (chrome-molybdenum and various stainless steels) than competitive products, an advantage of immense importance in fulfilling the customer's requirements.

4 In many sizes Southwest "Monoball®" self-aligning bearings readily replace the corresponding sizes of many antifriction rod end bearings, where used for the self-aligning feature under vibration. Sales here are on performance, not on price. For these uses it is safe to say Southwest would originally have been specified, if then known, because replacements now are tending steadily to Southwest.

Present-day operating conditions require from the "Monoball®" self-aligning bearings use of a tough metal in the ball and race. Originally the *ball* was made of SAE 52100 *steel* and the *race of high strength bronze*. For heavy duty service aircraft the bronze race is no longer used; a tougher metal is now used. Here the use of SAE 4130 steel, "chrome-moly" and stainless, is demanded, which Southwest alone is in a position to supply (in a two-piece bearing) as stated in Point 3 above. Higher temperature operations are also required. Jet propelled aircraft produce temperatures as high as 1000 deg F. These call for heat-treated stainless steel balls and stainless steel races. Only Southwest can supply these bearings in the two-piece construction. The purpose of "Monoball®" self-aligning bearings is to allow the shaft or bolt, which passes through the ball (a close prescribed tolerance between the ball and race) to self-align in any direction without any bending strain on the shaft or bolt, housing or structure, also to allow misalignment in fabrication of component assemblies.

The self-alignment feature is secured by an internal self-aligning design where a single ball operates on an internal spherical surface in the outer race or ring.

1. *Support for Actuating Cylinders*

"Monoball®" self-aligning plain bearings have been applied to the trunnions of hydraulic pneumatic cylinders, also "Monoball®" rod ends being used on the ends of cylinder rods, to take bending deflections without damage to structure. The bearings, both plain and rod end types, take care of the heavy loads during flight and operation on the ground.

2. *Retractable Landing Gear*

There are many joints and levers in the conventional landing gear of aircraft for which the "Monoball®" self-aligning bearing is well adapted. While it has been general practice to use plain bushings or bearings for these joints, it has been found that Southwest "Monoball®" self-aligning bearings enter readily into the design and are being used in increasing quantities, due to high static loads and alignment problems.

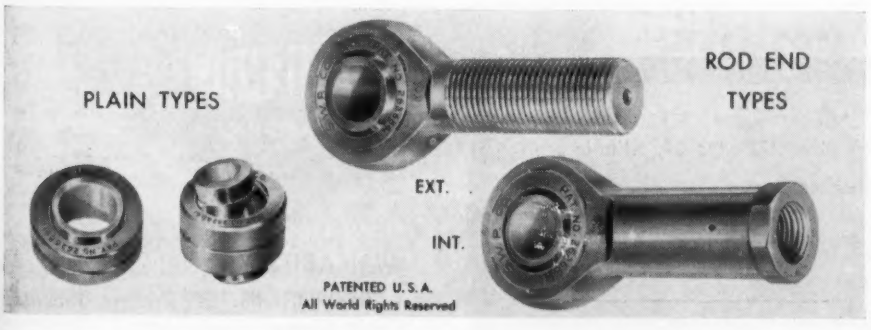
3. *Landing Gear Strut. Drag Link Struts*

Due to severe misalignment in these struts, the ordinary plain bushing or bearing does not provide for self-alignment, and is severely strained along with structure deflections. The Southwest "Monoball®" self-aligning bearings are being used in the ends of these struts with no undue strain on the "Monoball®" bearing or structure.

4. *Landing Gear Trunnions—Main*

One typical application: while it is desirable to use antifriction bearings in these locations, the antifriction bearings cannot take care of the high static load condition which must be carried by the bearing throughout the flight period; also, due to the weight of the gear being suspended, heavy shock loads are placed on the bearing in travel through rough air. Due to smaller space requirements and higher allowable loads required by supersonic aircraft, the Southwest "Monoball®" bearings with their higher capacities (loads), small weight, and outside diameter, combine nicely with the present design.

[1] "Monoball®" (Trademark Registered®).



"Monoball®" Self-Aligning Bearings, description and application, U. S. Patents Nos. 2626841, 2724172, 2728975, and other patents pending.

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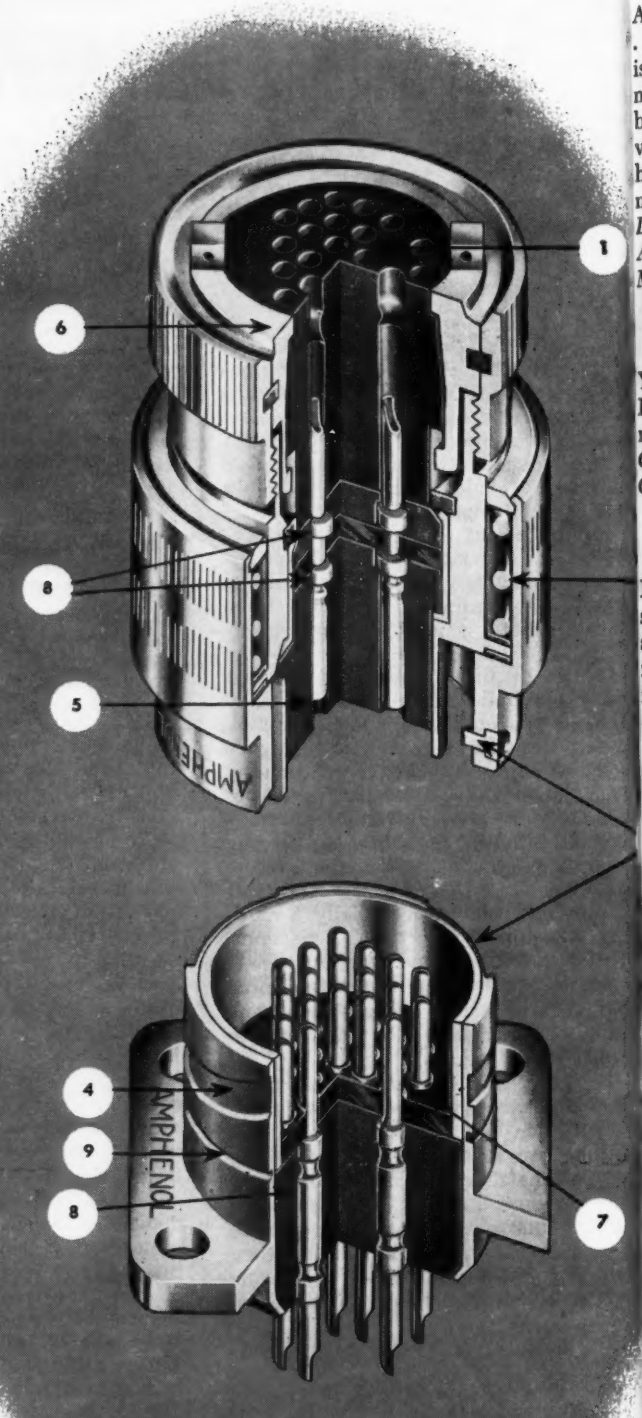
FEATURES

1. Environmentally sealed with unitized back end grommet. (Also available with provision for potting.) Either grommet seal or potted seal meets moisture resistance requirement of MIL-C-5015C, Paragraph 4.5.21.
2. Spring-loaded coupling ring provides a positive locking action in the bayonet slot, and a constant compensating force which eliminates the effects of resilient face seal compression set.
3. Stainless steel bayonet slots and pins reduce wear and frictional characteristics. The three pin bayonet coupling minimizes the rocking action of the mated plug and receptacle.
4. Flattened incline angle of bayonet slots reduces mating force requirement.
5. Hooded contacts resist test prod damage as defined in Paragraph 4.5.14 of Amphenol Specification 340-43-2108.
6. Unitized grommet seal; clamp and grommet form a single unit for ease of assembly and maintenance.
7. Face seal gasket with individual barriers to isolate each contact.
8. Hard insert dielectric (plus resilient face seal) positively retains contacts with no possibility of contacts being pushed out of the insert.
9. A visual full engagement indicator is included in the design to insure the user that he has fully engaged the connectors. The indicator is an orange line around the receptacle shell.

- When using mated sealed connectors, no derating for altitude is necessary at 70,000 feet.
- Test voltage 1,500 volts RMS 70,000 feet on sealed connectors.
- Vibration per Method 204 of MIL-Std-202A. 10 to 2,000 cps at 20 g's.
- Temperature cycling range per MIL-C-5015C, Paragraph 4.5.3 increased to 257°F. maximum and —67°F. minimum.



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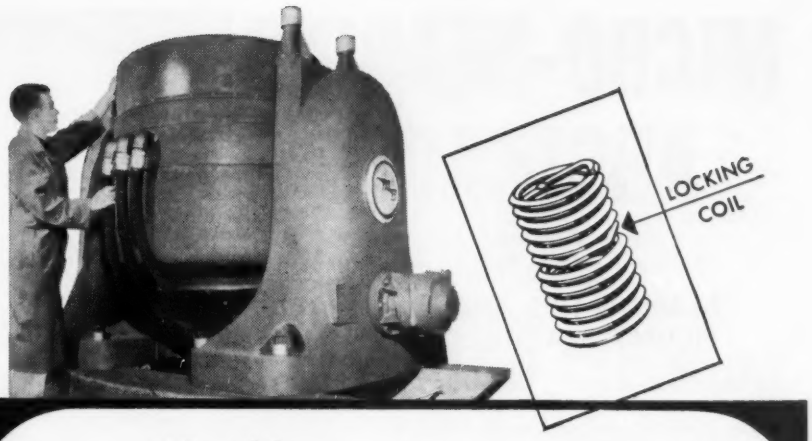

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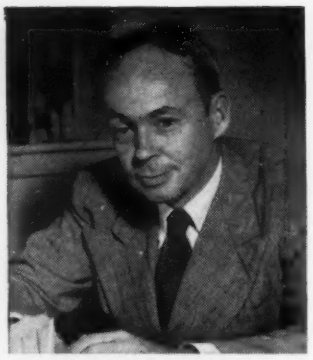
FOR MORE INFORMATION CIRCLE 17 ON INQUIRY CARD

MICRO-BEARING ABSTRACTS



by **A. N. DANIELS**, *President*
New Hampshire Ball Bearings, Inc.

BEARING FITS AND FITTING PRACTICES

As shown in *Fig. 1*, the fitting of Micro-Bearings, like the fitting of larger ball bearings, chiefly involves the clearances between the inside diameter of the housing and the outside diameter of the bearing; the bore of the bearing and the shaft diameter.

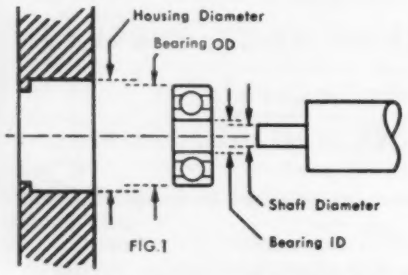


FIG.1

The achievement of the desired fit by dimensioning is illustrated in *Fig. 2*. The bearing ID is represented by the top blocks and the shaft OD is represented by the lower blocks. Such a block diagram could also be applied to housings and bearing outside diameters. In this block diagram, it will be noted, the bearing ID is represented by a .00015 tolerance with a similar tolerance for the shaft. A resulting fit of line to line to .0003 loose is shown.

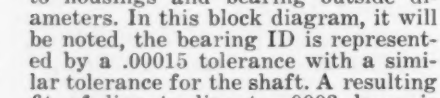


FIG.2

An interference fit not tighter than line to line is suggested for the following reasons:

1. *Difficulty in assembly.*
2. *Difficulty in disassembly. This is often more hazardous than the assembly operation and may result in total bearing destruction.*
3. *Reduction in radial play.*
4. *Danger of bearing ring conforming to possible poor geometry of mating shaft or housing.*

TOLERANCE DISTRIBUTION

The maximum .0003 loose condition shown in *Fig. 2* may be excessive in some applications. The fitting problem then resolves itself to reducing this extreme, and yet maintain the maximum tight fit of line to line. The looseness may be reduced by redimensioning the shaft to .12490/.12475 as shown in the block diagram, *Fig. 3*.

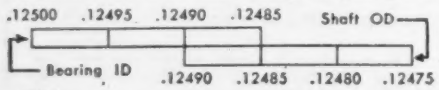


FIG.3

If the frequency distributions of shaft and bearing ID sizes were statistically normal, the modal fit of all parts would be 0.0001 loose. Accordingly, an insignificant percentage of parts would be mated to the extreme values, and for practical purposes could be ignored.

With regard to bearings' outside diameters and bores, however, normality of the distribution curve cannot be assumed. During the grinding operation, the "most metal tendency" tends to skew the frequency distributions for bearing ID's and OD's in the direction of most metal.

In grinding and finishing shafts and housings, similarly skewed distributions occur.

Operating on a modified probability distribution of tolerance is possible if the volume of parts is sizeable. But the approximate distribution of shaft and housing sizes must be verified if this method is to be used.

MATERIALS and SURFACE FINISHES

The ease of assembly is also affected by materials and finishes. The following factors must be considered:

1. *The galling characteristics, hardness and ductility of the materials involved.*
2. *Finish lay patterns produced by various tools and techniques used.*
3. *R M S surface finish values achieved.*
4. *Geometry of shafts and housings as regards out-of-roundness, taper, etc.*

The possible combinations of these elements in any single application are so numerous that their gross effect can only be ascertained by trial and error, or by a detailed study of operations on individual applications. A more complete discussion of fitting practices, including sizing methods and coding, is found in our design handbook.

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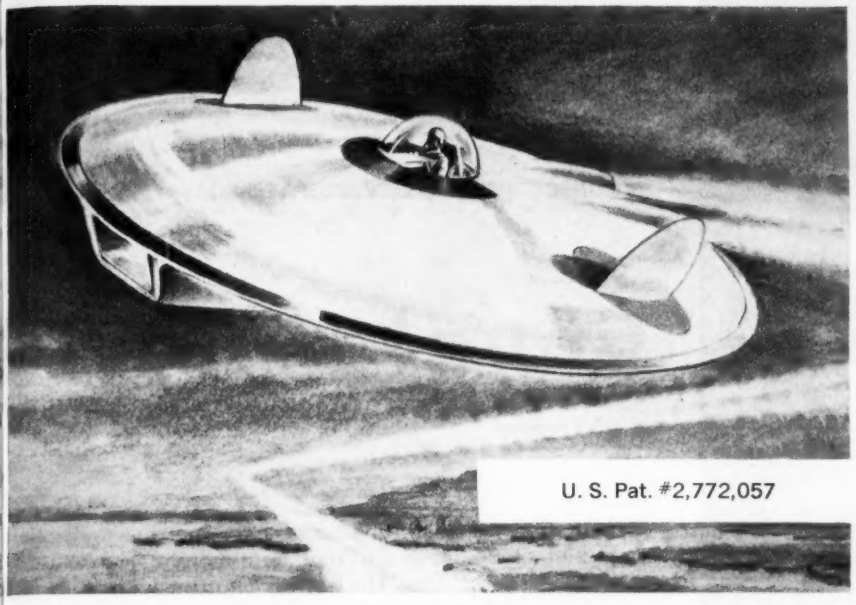

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John C. Fischer, Jr., San Diego professional engineer, one of the winners in the 1957 MARS Contest. Mr. Fischer's project, "Saucer Secret?," is featured in the MARS presentation on this page.

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The MARS Outstanding Design Contest of 1957 created such wide interest that MARS Pencils is sponsoring another contest for 1958.

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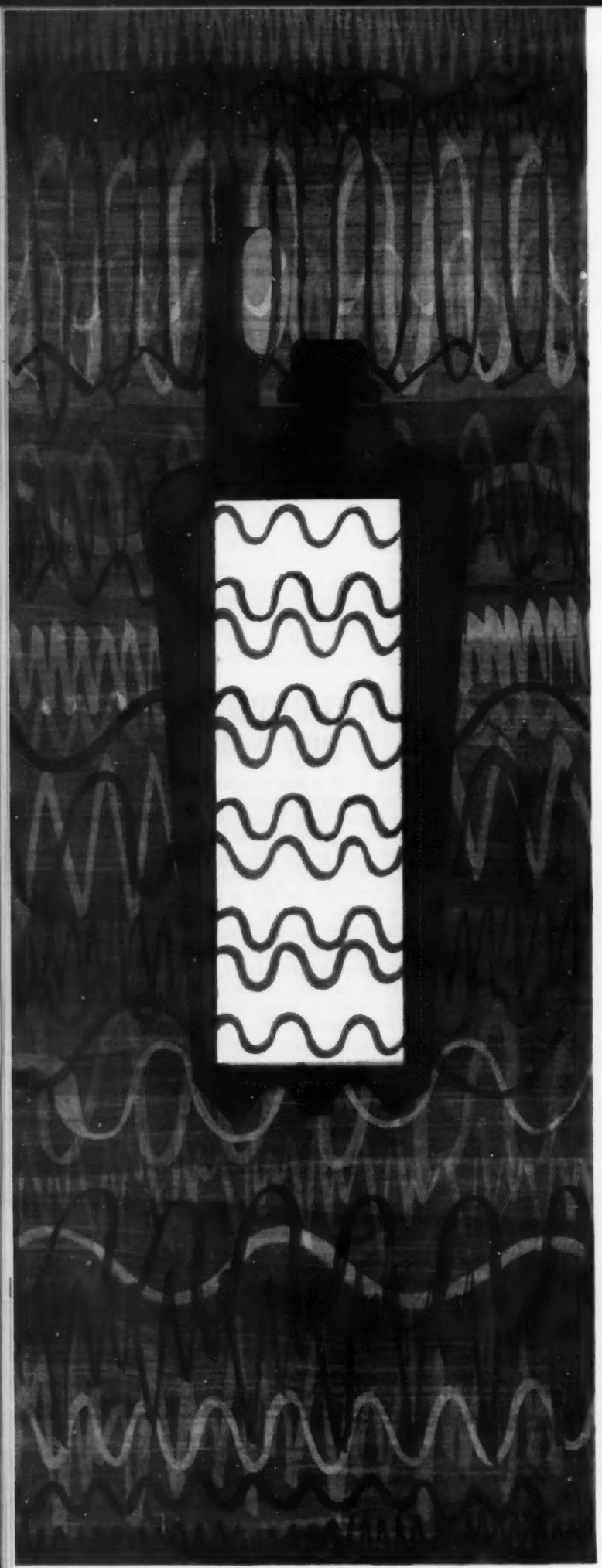

COMPONENTS-DESIGN

MAURICE ST. CLAIR, Varian Associates

Coupled Cavity Ta

Stabilization of microwave oscillators by direct reaction from high-Q circuits is a technique in more or less common use since World War II. Recent improvements in techniques of mode suppression have made practical the use of relatively large resonators which have Q's approaching those obtained from quartz crystals, yet which can be tuned over almost unlimited range. The relative simplicity of coupled cavity stabilization in comparison to other known stable sources gives it a large competitive advantage in systems requiring stable oscillators.

STABILIZATION OF KLYSTRONS

In reflex klystrons, short-time frequency instabilities are caused by the inherent random shot noise in the electron beam and by external perturbations. The effective noise bandwidth is inversely proportional to Q^2, so that an increase in the equivalent Q of the circuit will rapidly decrease the bandwidth. The effects of external disturbances on the klystron—power supply effects, load effects, temperature effects, vibration—are reduced in direct proportion to this equivalent Q.

The equivalent circuit of klystron and a stabilizing cavity is shown in Fig. 1. Under conditions of matched cavity input, synchronous tuning of the klystron and cavity, and small G_s, the factor by which a given cavity improves klystron stability, S, is simply expressed by the relation

$$S = 1 + \left[Q_o/(Q_E)_K \right] (1 - P_o/P_i),$$

in which Q_o is the unloaded Q of the stabilizing cavity, $(Q_E)_K$ is the external Q of the klystron, and P_o/P_i is the cavity insertion loss, P_o/P_i is typically set between 0.1 (10 db) and 0.5 (3 db). Actual choice of insertion loss is based on a compromise between stability factor requirements and power output requirements. The only kind of klystron frequency perturbation not reduced by the factor S by cavity stabilization is that due to changes in load VSWR. The stability against load perturbations is improved with cavity stabilization by a factor S P_i/P_o. Thus the load stability factor is always larger than S.

CAVITY DESIGN

A few typical numbers in the equation for S can be used to indicate the sort of results obtainable with cavity stabilization of reflex klystrons at X-band. $(Q_E)_K$ for such klystrons is typically about 700. To obtain a stability

tabilization of Klystrons

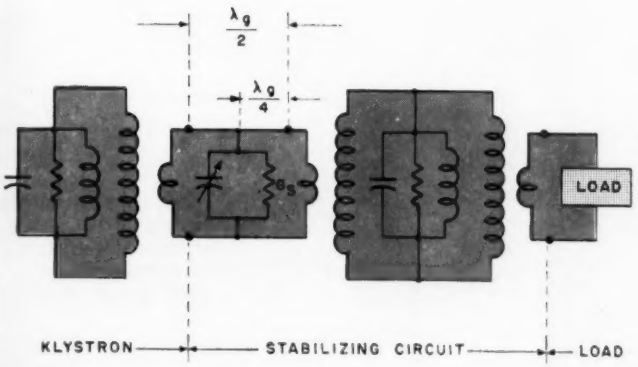

FIG. 1—Equivalent circuit of a klystron and stabilizing cavity. Analysis of this circuit reveals that when the klystron and stabilizing cavity are tuned to the same frequency, f_o, three possible frequencies of oscillation result from the presence of the section of transmission line connecting the two resonant circuits. By introducing a shunt conductance, G_s, it is possible to completely suppress the two undesired frequencies so that oscillation can take place only at f_o. The insertion loss resulting from the introduction of G_s is typically only a small fraction of a decibel and the reduction of equivalent circuit Q is less than 15 percent. The variable shunt capacitor in parallel with G_s adjusts the effective line length between resonant circuits to exactly $\lambda g/2$. This may simply be a capacitive screw in the connecting waveguide. Actually, stabilization is possible with connecting line length of $n\lambda g/2$, where n is any positive integer; but large n requires large G_s and reduces circuit Q and stabilizing range.

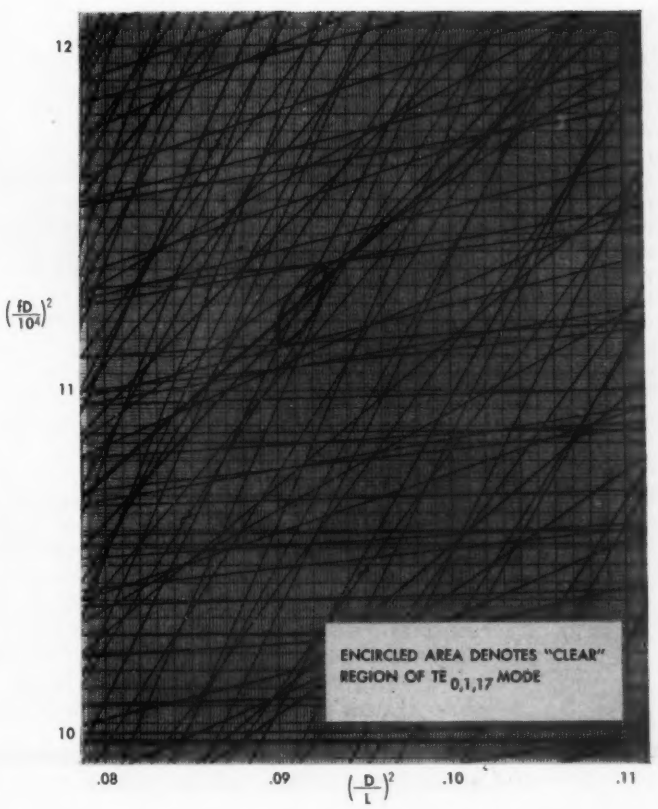

FIG. 2—Section of mode chart. The heavy line passing through the circled portion of the TE_{01n} mode and the upper right-hand corner of the chart is the locus of points on TE_{01n} modes at which Q_o=150,000 (theoretical for copper). Units on the mode chart are f, megacycles; D, cavity diameter, inches; L, cavity length, inches.

factor of 15 with 3-db insertion loss, this typical klystron would have to be stabilized by a cavity having Q_o = 20,000, and if the losses due to G_s are taken into account, Q_o = 23,000. This can be accomplished in a small cavity operating in the circular electric TE_{011} mode. Such cavities, when temperature compensated, are very effective in systems requiring one or two megacycles stability over extended periods of time under adverse conditions and power supply fluctuation.

To obtain a stability factor of 150 with 3-db loss, Q_o of 240,000 would be required. A compromise on power output, allowing 10-db insertion loss, leads to a design calling for Q_o = 133,000. To obtain Q's of this sort one must build cavities to operate in the higher order TE_{01n} modes. Cavity design in this region is greatly complicated by interference from hundreds of other TE and TM modes crossing the desired TE_{01n} mode at random intervals. For this reason work was initiated at Varian Associates toward design of a stabilizing cavity with theoretical Q_o of 150,000 in which all but the desired circular electric TE_{01n} modes were suppressed.

Figure 2 is a portion of a mode chart centering on the region where a cavity with Q = 150,000 has minimum volume. A method was sought to lower the Q's of all undesired modes to the point where these modes would couple negligible energy to or from the connecting wave-

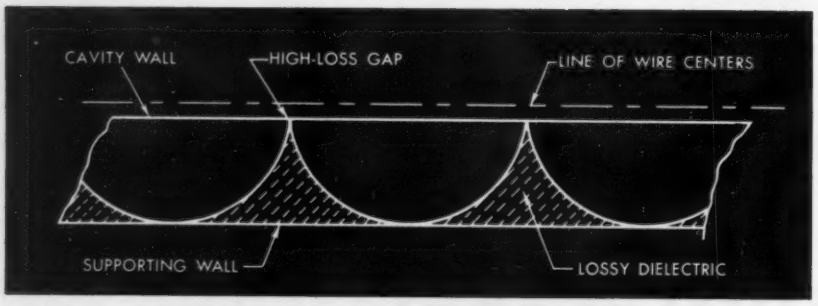

FIG. 3—Section of cavity wall designed to be extremely lossy to longitudinal currents. The inner wall of the cavity was wound with wire. This wire, which forms a very low-pitch, tightly wound spiral, was embedded in polyiron cement in place of the former copper liner. After curing the cement the inner wall was machined to cut away half the diameter of the wire and honed to produce a smooth interior finish.

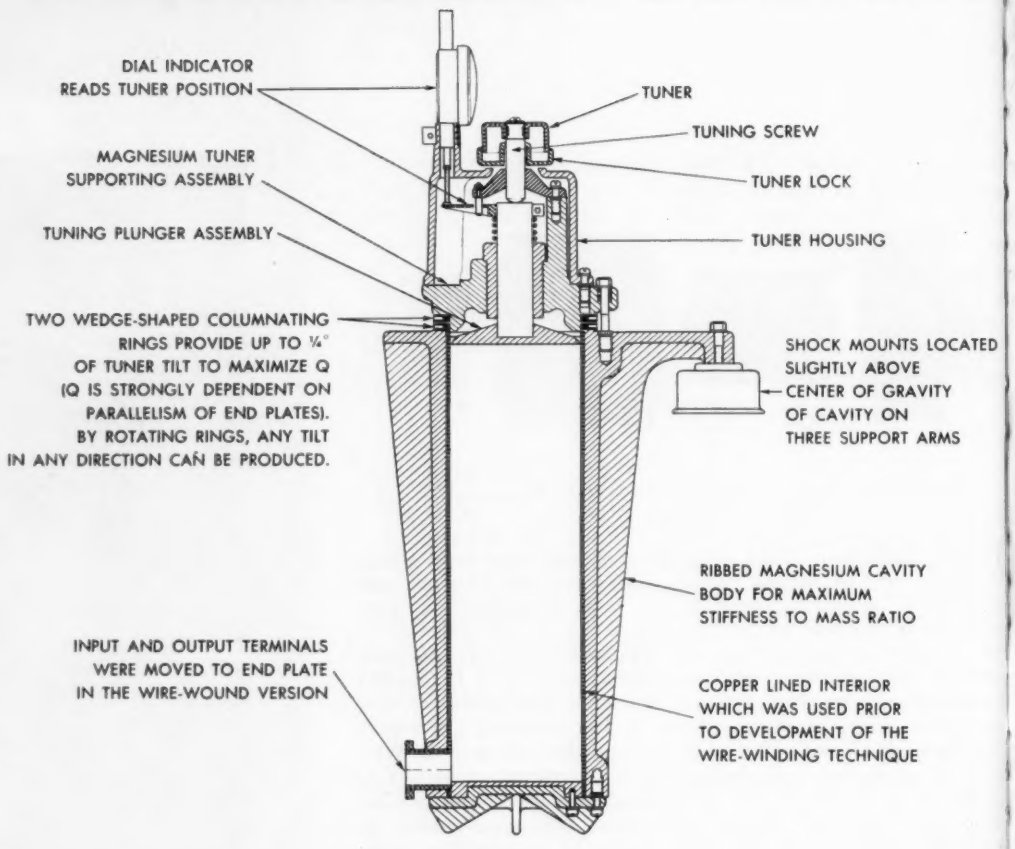

FIG. 4—Cross section of cavity. The unit is built of ribbed magnesium castings for maximum rigidity and lightness. Tuner travel is monitored on the dial indicator at the top, and parallelism of the polished copper end plates is adjusted by means of rotating two wedge shape columnating rings which support the tuning mechanism on the cylinder body. Coupling is accomplished at the sides of the cavity ¼ wavelength from the stationary end plate.

guides. One thing that all but the circular electric (TE_{0mn}) modes in waveguides or cavities have in common is longitudinal current components in the cylinder walls. If the cylinder wall can be made extremely lossy to longitudinal currents, all but the circular electric (TE_{0mn}) modes will suffer a sharp reduction in Q. Figure 3 illustrates the design of a cavity wall having the desired lossy characteristic. Figure 4 is a cross section drawing of the cavity.

In order to suppress the TE_{02n} circular electric family which suffered no reduction in Q with the wire winding technique, coupling irises were subsequently moved to that radius in the end plate where the currents in the TE_{02n} family are zero. This end plate coupling has an additional advantage over the design of Fig. 4. Irises for coupling the desired modes are smaller and therefore couple less strongly in general to other undesired modes. One disadvantage of end plate coupling is the possibility of their increasing cavity microphonics by increasing the mass and reducing the stiffness of the end plate.

Tests of the resulting cavity revealed that the TE_{13n} family of modes was not sufficiently suppressed by the wire winding technique, since longitudinal current components in this mode family are very small. However, this mode has heavy current concentration at the center of the end plates where currents of the TE_{01n} modes approach zero. Accordingly, a device was constructed for coupling energy out of the TE_{13n} modes—for lowering the Q of these modes—at the center point in each end plate, Fig. 5. Figure 6 is a photograph of the final design of the stabilizing cavity. Figure 7 is a mode chart showing that the final design fulfills the objective of suppressing all but the TE_{01n} mode family.

OPERATION

Operated between 8500 and 9600 mc, the cavity yields a stabilized modulation sensitivity over the whole band of about 8 kc/volt. The stability factor varies between 100 and

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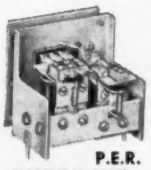

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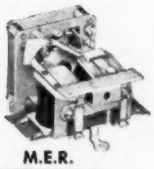

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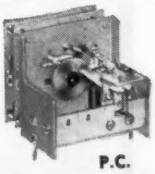

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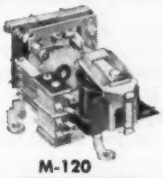

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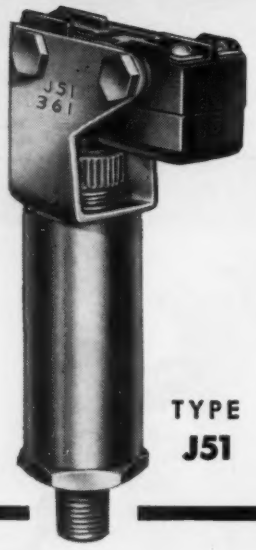

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200 as a function of frequency. Thus, with a supply having less than 1 millivolt ripple the contribution to FM from the reflector would be less than 8 cycles. Measurements of short-term stability, beating two stalos together, yield short-term relative stability better than 8 cycles in 200 ms.

The maximum number of tuning adjustments on the stabilizing cavity is three: frequency, phase, and coupling. For best results all must be used when frequency changes greater than 500 mc are made. For frequency changes on the order of 100 mc it is only necessary to adjust the tuner. When a sine wave sweep is available for the klystron reflector and an oscilloscope can be used to display power output vs sweep voltage, adjustment of the stalo for optimum performance at any frequency is simple.

The temperature coefficient of frequency of the cavity is roughly that of magnesium—somewhat over 200 kc per degree Centrigrade. Cavities can be designed to have almost any desired temperature coefficient—positive, negative or approaching zero—by using Invar, which has a very low temperature coefficient of expansion, and brass in the proper configuration.

Small cavities are commonly made of Invar, but if the large cavity described here were made of this heavier metal, it would weigh about 50 pounds rather than 18 pounds. This increased mass would result in a tendency to increased microphonics. However, if temperature compensation of the cavity were required, Invar or similar low expansion material would have to be used.

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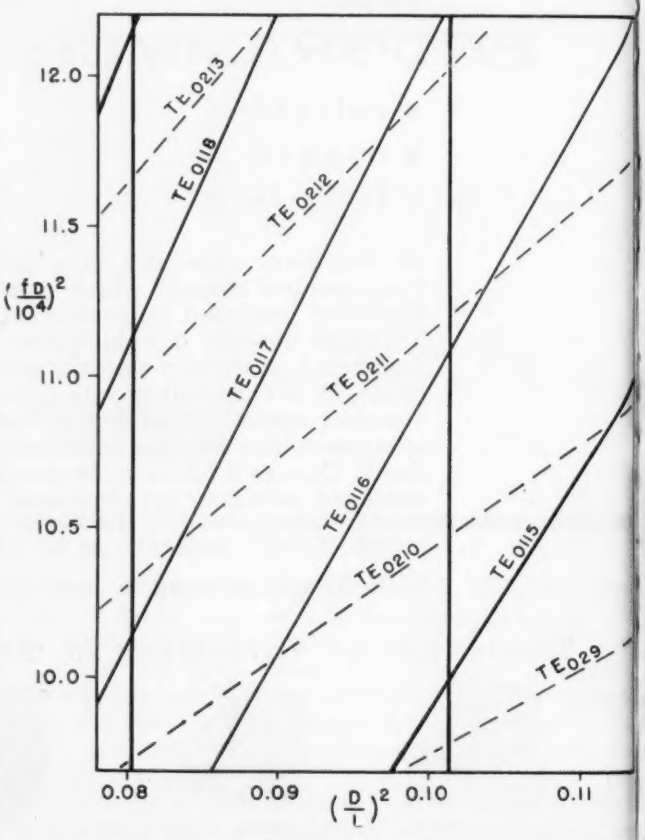

FIG. 6—Mode chart of the final design. For a 3.6 inch diameter cavity this chart covers the range between 8650 mc and 970 mc. The only detectable modes in this region are those of the TE_{01n} family. The vertical lines on the figure represent the limits of tuner travel. It can be seen that by skipping from mode to mode any frequency in X-band can be used. The upper end appears to be limited only by crossings of the TE family at 12,900 mc, although no measurements have yet been made above 11,000 mc. The lower end is limited by tuner travel at less than 8200 mc.

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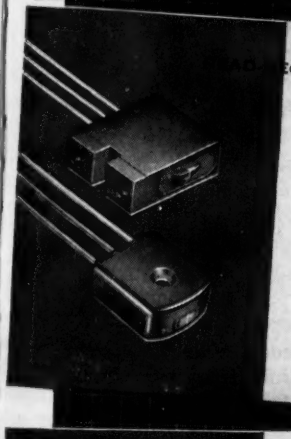

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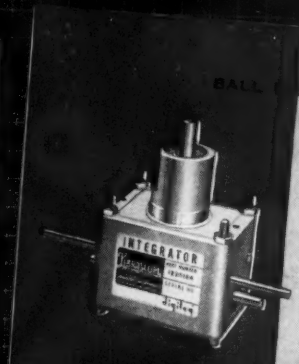

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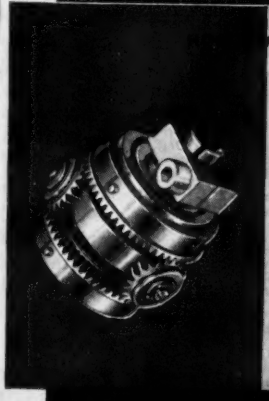

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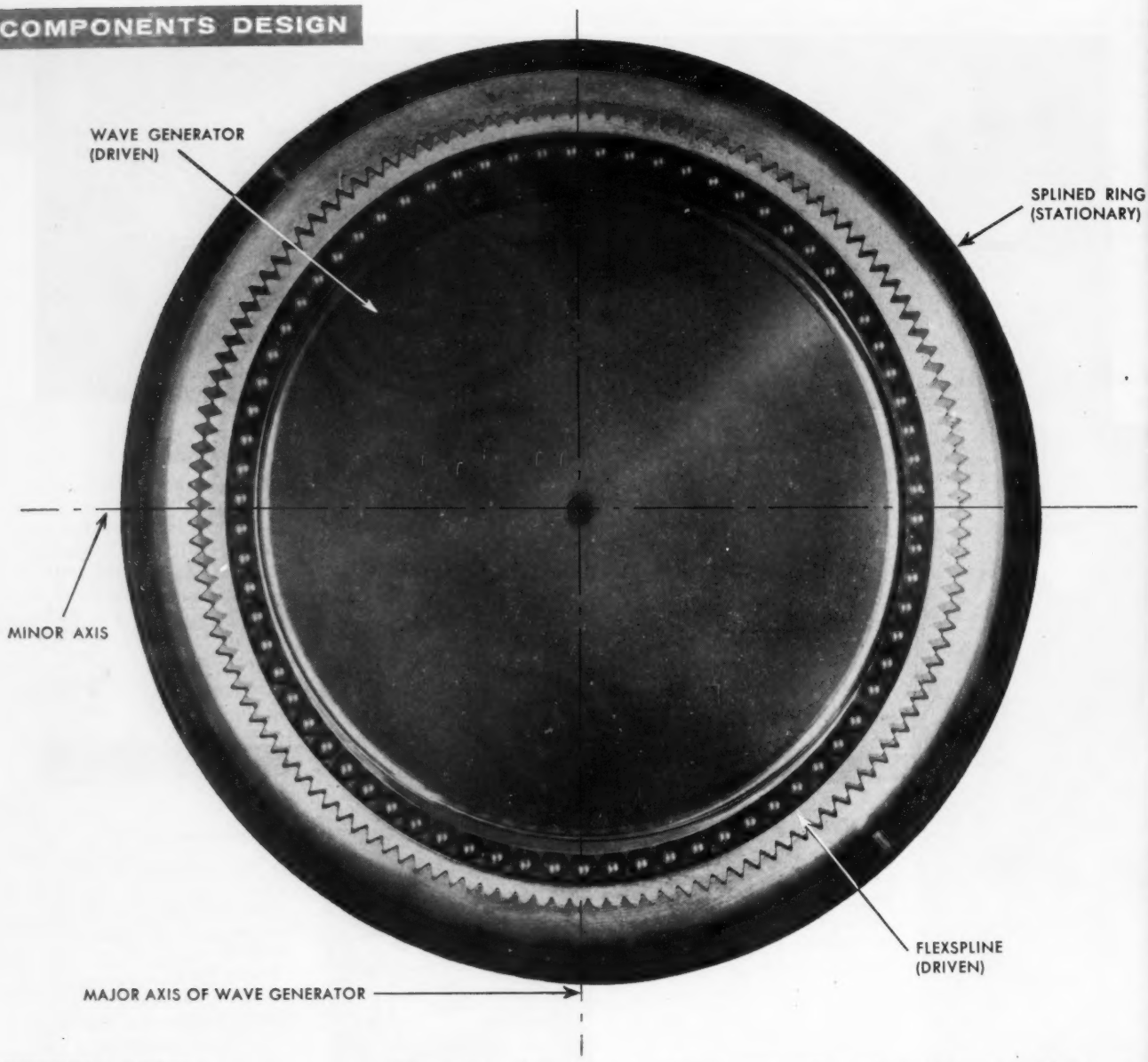

FIG. 1. New drive principle can be most readily understood in its application to th rotary version with as little as three basic parts. A splined ring with internal teet mates with a flex spline having external teeth. These teeth are all of one circula pitch and the areas of engagement are in full mesh. The inside of the flex spline act (in the version shown) as the outer race of a ball bearing. The inner race is elliptic and causes the teeth of the spline to be in full engagement along the major axis o the ellipse. Along the minor axis the teeth are fully disengaged. The inner race i called a wave generator, since rotation of the ellipse generates a traveling harmoni wave. As the wave generator is rotated it causes progressive tooth engagement. Th teeth are always in mesh along the major axis and out of mesh along the minor axi There are fewer teeth on the flex spline than on the splined ring; therefore, eac rotation of the wave generator moves the flex spline teeth a distance equal to th tooth differential between the splines. Where the teeth are meshed, they are stationary acting as splines in total area contact. The movement of the flex spline or driven mem ber is confined to that area where the teeth are disengaged. It is obvious that thi arrangement incorporates inherently great strength with negligible wear and noise. I many types of application, little or no lubrication of the teeth is needed.

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• LARGE MECHANICAL ADVANTAG Actual values up to several million t one can be positively and continuousl produced with simplicity and wit reduced package design.

• HIGH EFFICIENCY. Units have bee made where the only losses are in th anti-friction bearings and the hysteres effect in the flex spline. Both of thes losses are quite small. Even for larg

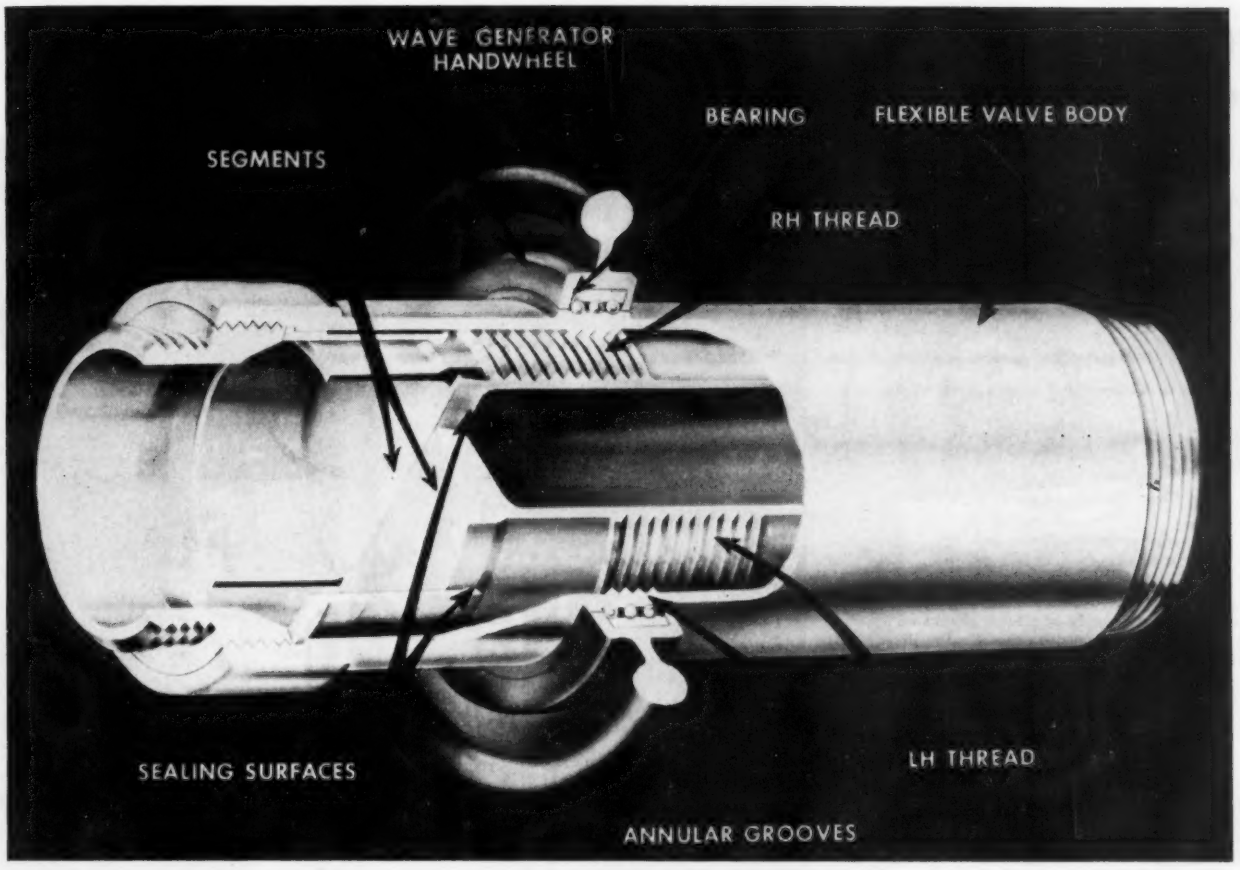


FIG. 2. Valve Drive. Using the harmonic drive principle of motion transmission a hermetically sealed valve can be made with all rotating parts outside the valve. Sealed within the valve are only two moving parts—valve closure segments. Movement and control of these parts by the external motor drive is through surfaces in almost pure rolling contact. Positive position indication is accomplished by a direct precise mechanical connection. The valve closes to a preset torque level.

mechanical advantages the efficiency remains exceptionally high. Normally there is only one internal part, which at its points of contact with the vessel wall is essentially stationary. As a result, friction losses are very low and lubrication is normally not required.

• PRECISE MOTION CONTROL. Harmonic drive produces motion by progressively advancing a controlled deflection wave along the periphery of a ring. Since this wave is sinusoidal without discrete steps, the output bears a precise functional relationship to the input with no backlash.

• OPERATION THROUGH A HERMETIC SEAL. Powerful motion can be transmitted and controlled directly through a vessel wall. The wall is left intact and no packing, stuffing boxes or seals of any type are used.

• SURFACE CONTACT. On many harmonic drive applications, transmission forces are resisted at the points of anchorage. At these locations, mating parts are fully splined together with an involute spline. The teeth are, at these points, stationary and fully in mesh. Hence, they are in surface contact, resulting in lower contact stresses and greatly improved resistance to wear.

• HUGE POWER-HANDLING CAPABILITIES. For a given size the power handling capability of a harmonic drive can be up to 100 times as large as that of conventional transmissions. A rotary design is possible in which 70 per cent of all the teeth are always fully in mesh and load bearing. The teeth are in stationary contact and function as an involute spline to anchor the power transmitting member while deflection incrementally produces the motion.

• RIGIDITY. Connecting links between the stationary member and the output are multiple in number, short in length, and of such shape as to produce a maximum resistive moment. For example, in the rotary version the output is coupled with the stationary member by a short tube. One end of this tube is splined, keyed, welded or integral with the output shaft and the other end is splined at several places directly with the stationary member. Torsionally, this is the most rigid coupling known.

• QUIET OPERATION. The only sound produced is by the ball or roller antifriction bearing in the wave generator. Other parts move into mating relationship at the peak of a harmonic or sine wave where their contacting velocities and sound radiation are negligible.

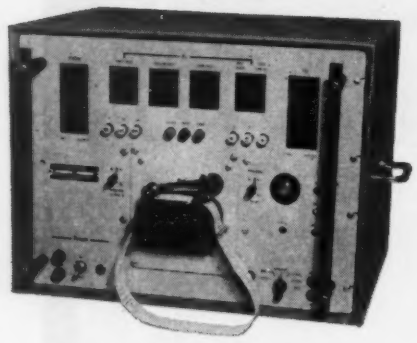
• SMALL SIZE AND LIGHT WEIGHT. For a given power transmitting value, the size and weight of a rotary harmonic drive are considerably less than that of an equivalent power transmission. As the mechanical advantage or the torque capabilities increase, this difference is accentuated. For high gear ratios or high torque values the size and weight of a harmonic drive is but a small percentage of that of a transmission of comparable performance.

• SIMPLICITY. Fundamentally there are only three parts—a housing, an input wave generator and an output. Complete working units have been made with a total of only these three parts. These parts tend to be self supporting and self centering. Additional structure and complication are added only for foreign matter exclusion, absorption of exterior lateral forces, assembly convenience or to facilitate manufacture.

• MODERATE STRESS. By controlling the deflection wave and making it of simple harmonic form deflection stresses are normally as low as 10 to 25 percent of those encountered in conservative spring design. Area con-

ROBOTESTER

The easiest way to automation



ro'bo-tes'ter, An electronic device which will perform a series of circuit checks on an assembled chassis, automatically indicating failures due to shorts, opens, or out of tolerance parts, etc. Uses punched tape to set up tests.

ROBOTESTER offers a technique of automatic testing for the small run as well as the high-production system. The unique punched-tape programming permits fast set-up, fast change-over, fast correction. No bulky jigs or test units... the entire test program for a complete system can be stored in your pocket! ROBOTESTER has reduced test time for its users to 20% of manual testing, and without weeks of jig-building. Write for complete information and circuit description.

SPECIFICATIONS

Measurement: DC resistance

Range: 1 ohm to 10 megohms

Tolerance: 5, 10, or 20%

Sequence: Any. Tests in random order, above or at ground

No. of measurements: Between any 2 of 240 points

Programming: By punched paper tape

Tape preparation: By user; punch supplied

Speed: 100 tests per min., max. average 60-90

Tape life: Over 25,000 cycles

Maintenance: Plug-in subassemblies

Specialized automatic test equipment and calibration equipment is also available from Lavoie Laboratories. Write us.

Lavoie Laboratories, Inc.

Matawan-Freehold Road
Morganville 18, N.J.
MAtawan 1-2600

CIRCLE 23 ON INQUIRY CARD

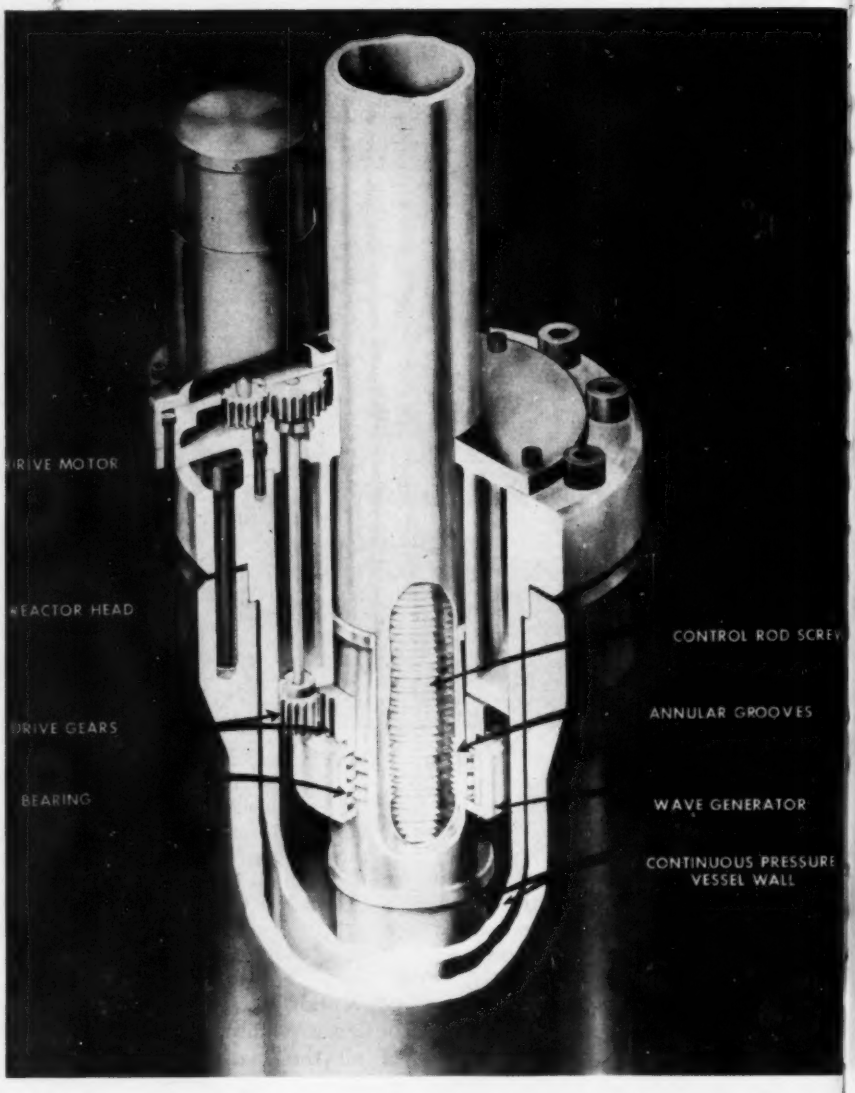


FIG. 3. Linear Drive. External rotary motion produces internal linear motion throu a hermetically sealed tubular wall for control of a nuclear reactor. All motion g erating parts are outside the wall. The internal screw is engaged with threads on t inside of the tube at several points, or areas. These contact areas rotate around t screw by means of propagation in the tube wall of a harmonic deflection wave. Lar linear forces are generated with precise control. Since the inside screw is always positive mechanical interlock with the outside rotary motion, positive indication o be accurately obtained from the outside.

tact on the mating surfaces reduces the surface contact stress to a very low value. Since shear stresses are distributed over a large percentage of the teeth they are also of moderate value.

Circle No. 211 on Inquiry Card

WORTH FILING

Guide to Better Casting

31-page booklet contains helpful data on factors influencing production sound zinc alloy die castings with go surface finish. Factors such as all composition, standard specificatio temperatures, metal injection pressur gating, venting, quenching, care dies and machines are considered. I cluded in the booklet are discussions common faults or defects in castin what causes them, and how they m be avoided. Examples of defects d cussed are shrink holes, gas hol porosity, flow lines and blooms, ha spots.

Source: Henning Brothers & Smith, Inc., Brooklyn, New York

For your copy: Circle No. 202 on Inquiry C

Specify SANDVIK *Precision-Tailored* Spring Steel

FOR ACCURATE FLATNESS, STRAIGHTNESS, WIDTH, GAUGE AND EDGE FINISH *PLUS* SPECIFIC PHYSICAL PROPERTIES

SS-138

When you require specific physical properties combined with accurate dimensions in spring steel, call Sandvik.

From composition, through processing to the finished strip, Sandvik has had long experience in precision-control. That is why you find Sandvik steels used for feeler gauges, watch springs, compressor valves, camera shutters, reeds, shock absorbers and many other exacting spring steel applications.

Sandvik supplies cold rolled specialty strip steels —

- **In special analyses for specific applications.**
- **Precision-rolled thicknesses to fit your requirements.**
- **In straight carbon and alloy grades.**
- **Annealed, unannealed or hardened and tempered — scaleless or polished bright, yellow or blue.**
- **With square, round or dressed edges.**

Sandvik stocks a wide variety of qualities and sizes. In addition Sandvik has Rolling, Slitting, Edge-Filing and Hardening and Tempering facilities.

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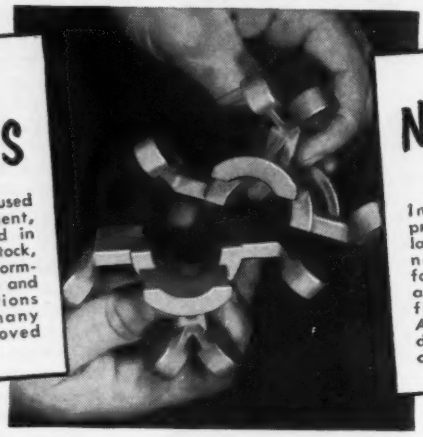
FOR MORE INFORMATION CIRCLE 24 ON INQUIRY CARD

How Industry Uses INVESTMENT CASTING to cut production costs!

WAS 6 PARTS

An intricate collar, used in sonar equipment, originally machined in 6 parts from bar stock, required blanking, forming, pre-machining and welding. Operations that created many problems and proved too expensive.



NOW 2 PARTS

Investment Casting produced the same collar in 2 parts. It eliminated all blanking, forming, pre-machining and welding. It simplified final assembly. And it materially reduced the cost of production.*

*Details on request

Send today for our new 12-page booklet, "Modern Precision Investment Casting." It tells you the "how and why" of, Investment Casting.

If you have a precision parts problem, perhaps Investment Casting can help you. If the part measures 6" x 5" or smaller, if it weighs 3 lbs. or less, if it requires starting tolerances as close as plus or minus .005" per linear inch, if it now needs 5 or more fabrication steps, *maybe you NEED Investment Casting.*

ALEXANDER SAUNDERS & CO.

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WAtkins 4-8880

Photo and data courtesy of The International Nickel Co., Inc.

FOR MORE INFORMATION CIRCLE 26 ON INQUIRY CARD

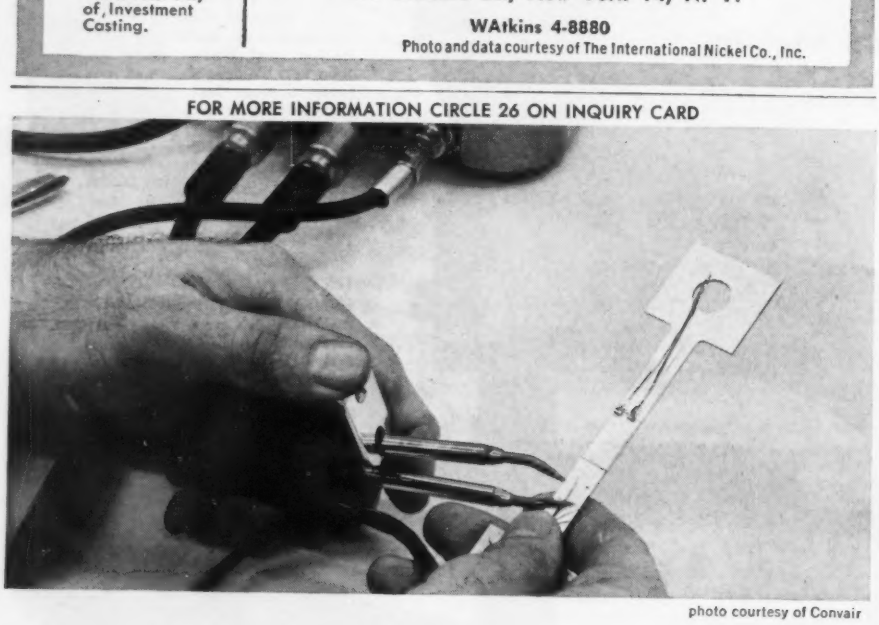

photo courtesy of Convair

WELDMATIC PRECISION WELDING JOINS "DIFFICULT" MATERIALS INSTANTLY FOR CONVAIR

Making spot welds in millisecond time, this Model 1016 Weldmatic Welder speeds up instrument assembly involving difficult materials at Convair. Here it's used to assemble 28-30 gauge iron thermocouple leads to low-carbon steels, aluminum alloys and magnesium alloys. Sturdy joints provide unusual resistance to acceleration, vibration and high temperature; joint uniformity provides high reliability. Write for technical data on the Weldmatic line.

WELDMATIC DIVISION OF UNITEK CORPORATION
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FOR MORE INFORMATION CIRCLE 25 ON INQUIRY CARD

HIGH TEMPERATURE AIR MOTOR

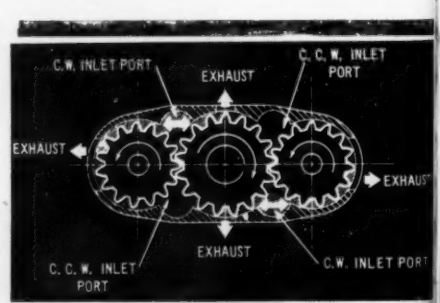
Pressure Relief Design Produces Fast Response

A new air motor follows electronic modulation in ambients to 1000 degrees F and with 400 degree F temperature differentials between moving parts and housings. Light weight and corrosion resistant materials with stable characteristics at high temperatures were fabricated to close tolerances in accordance with special designs to create motors with remarkable performance achievements.

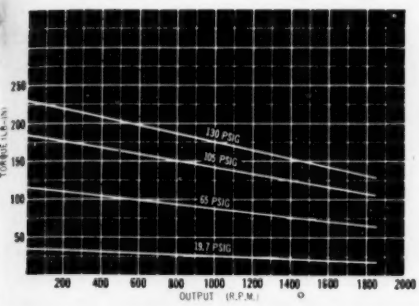
Lear, Incorporated, Grand Rapids, Michigan, states that one model accelerates from zero to 100 rpm in 0.00004 second against 20 pound-inches torque with a 30 psig supply. For lightweight applications, some units weigh as little as three pounds.

Power output is proportional to supply pressure and unaffected by temperature, and a typical motor weighing 20 pounds delivers 30 horsepower from 300 psig. High starting torque, instantaneous reversibility, and equal efficiency in either direction of rotation give the unit versatility for high-temperature, jet engine applications.

Ambidextrous operation, thermally unaffected output, quick frequency response, and high torque resulted from the use of a positive displacement, pressure-relief type of motor enhanced by a new valve design requiring small control forces. The main design problem was to produce a motor to operate



Schematic above illustrates airflow through the motor. Units are controlled by an external mechanical signal that drives a fully balanced, centered, 4-way barrel pneumatic valve. Rotating the valve pressurizes the motor for either clockwise or counter clockwise rotation. Overcoast of these units is limited by dynamic braking resulting from the differential pressure produced by the motor acting as a vacuum pump on the inlet side and a compressor on the exhaust side when the valve is moved to the center "off" position.

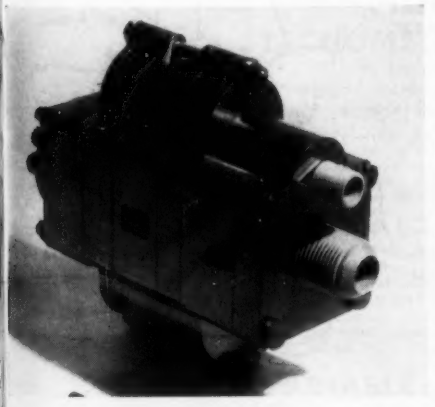


Typical performance curve of Lear's air motors illustrates the unusually high torque at starting for a low operating rpm. Performance is similar to that of a direct-current electric motor. Torque is proportional to gage pressure of the supply air, and power output is unaffected by changes in temperature.

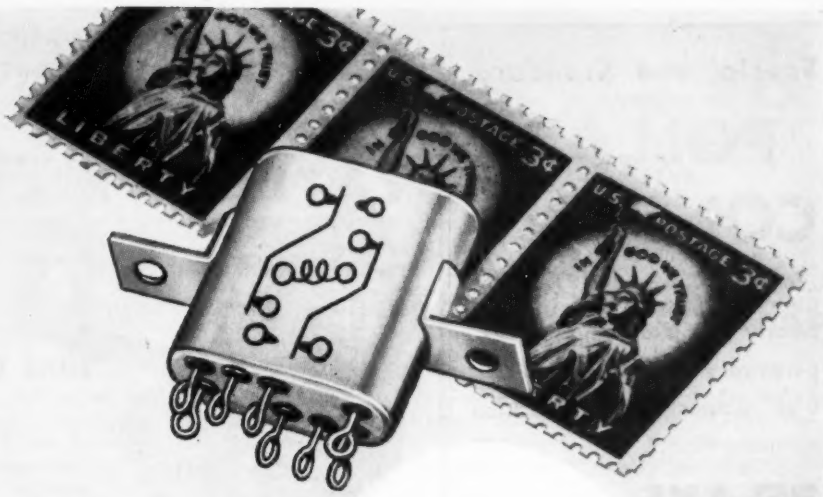
effectively at extreme temperatures and temperature gradients while maintaining small size and weight.

Advantage was taken of recent metallurgical advancements in cobalt and nickel alloys, steel super-alloys, and stellites in conjunction with high temperature magnesium alloys. These were thoroughly tested before final selection and matched to eliminate problems of differential expansion at high and gradient temperatures. Close control of room temperature assembly with tolerances approaching 0.0002 inch was kept to eliminate the danger of seizing. A lubricant-free, special bearing was designed because no available lubricant showed sufficient promise for the design objectives. Special geometry with a super-alloy was used to provide the necessary degree of freedom for high ambients.

Circle 151 on Inquiry Card



Lear has designed its units in compact narrow envelopes weighing as little as three pounds. Above is illustration of unit viewed from the input end. Contour of the housing was designed for ease of machining from high temperature metals. Low operating rpm of units minimizes complex problems of high bearing loads, high bearing speeds and dynamic balancing.



ADVANCE MV

HIGH PRECISION
SUBMINIATURE RELAY

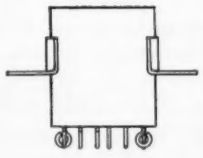
Big Relay Performance!

. . . crystal can size

Advance's MV rates superior to other high performance relays, yet is less than an inch long and weighs less than half an ounce. It meets military specifications and is designed for continuous use in the -65°C to 125°C temperature range. The MV has a life rating of 100,000 operations minimum at rated load. This relay is in production now and prompt delivery is assured. For computers, control systems, and every installation that requires both dependable performance AND miniature size . . . specify MV.

Available from stock at leading distributors all over the country

SPECIFICATIONS



VIBRATION	10 to 34 cycles per second at maximum excursions of .04"—34 to 2000 CPS 20G's acceleration
SHOCK	50G's for 11 milliseconds
LIFE	100,000 operations minimum at rated current
AMBIENT TEMPERATURE RANGE	-65°C to 125°C
DUTY	Continuous
OPERATING POWER	Nominal 1.2 watts at ambient temperature
CONTACT ARRANGEMENT	DPDT (2 Form C)
CONTACT RATING	2 amps resistive at 32VDC or 115VAC
CONTACT MATERIAL	Silver-Magnesium-Nickel, Gold-plated
CONTACT RESISTANCE	0.05 ohms
OPERATING TIME	5 milliseconds maximum at nominal power
RELEASE TIME	5 milliseconds maximum
ALTITUDE	Voltage breakdown of relay is 1000 volts AC at sea level—450 volts AC to 70,000 feet
DIELECTRIC STRENGTH	1000 volts RMS
INSULATION RESISTANCE	100 megohms minimum at 125° C
STANDARD COIL RESISTANCES	30, 120, 600, 1000, 2500, 5000, 10,000 ohms; others available
SIZE	0.875 high x .797 wide x .359 thick maximum
WEIGHT	0.45 ounces (maximum)
MOUNTING ARRANGEMENT	Angle bracket (as shown), strap bracket or plug-in
TERMINAL ARRANGEMENT	Solder-hook (as shown), or plug-in

ADVANCE RELAYS

ADVANCE RELAYS

ELGIN A DEPARTMENT OF ELGIN NATIONAL WATCH COMPANY
366 BLUFF CITY BOULEVARD, ELGIN, ILLINOIS

FOR MORE INFORMATION CIRCLE 27 ON INQUIRY CARD

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PLUNGERS FOR PUSH OR PULL
300 CUSTOM TYPES FROM 20 STANDARD PARTS
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IMPULSE
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PUSH PULL
ROTARY SELECTOR
TOGGLE

OUR ENGINEERS CAN HELP SOLVE YOUR PROBLEMS

Take advantage of POLLAK engineering design service. Our factory-trained engineers are available to help you solve difficult relay, switching and electrical control problems.

WE INVITE YOUR INQUIRY

JOSEPH POLLAK CORPORATION

DEPT. EM

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Boston 22, Mass.

CIRCLE 28 ON INQUIRY CARD

New split-wedge transducer was designed for operational or flight-test applications requiring accurate angle-of-attack or side-slip application. The two-pound transducer withstands accelerations up to 10g and has a range of ±25 degrees.

NEW VANE TRANSDUCER

Split-Wedge Measures Angle of Attack

A new approach to the problem of angle-of-attack measurement is represented in G.M. Giannini & Company, Inc.'s Angle-of-Attack Transducer. Their basic design objectives were to develop a heated, damped local angle-of-attack transducer that would be reliable, operational and easily produceable. A further necessary requirement was that the instrument meet or exceed MIL-T-25627(USAF) Specification.

Two of the most difficult design problems were: choosing the proper damping technique—magnetic, pnuematic, or viscous—to most adequately answer the size, weight, and performance requirements of the instrument; and a heating element and temperature controller that would combine high reliability with operational requirements of the instrument.

Giannini's engineers solved the first with the design of a simple viscous damping mechanism and the second with a high positive temperature coefficient heater element that eliminated a thermostat.

The unit consists of a heated vane geared to two output synchros. Damping is maintained to 0.5 of critical. A single, stainless steel-sheathed tubular type heater, cast as an integral part of the vane, extends down into the shaft for de-icing of the labyrinth seal. To insure that the information supplied by the instrument is usable, the dynamics of the vane had to be controlled within the specified requirements. Careful control of the system function and gear backlash maintains accurate electrical information of the physical phenomena sensed by the vane. The unit takes 0.075 second maximum to recover 63 percent of a step-input at 110 knots at sea level. Its overshoot is 0.5 degree maximum when the vane is released from a 3.0 degree deflection at 110 knots at sea level. Its sensitivity is 0.2 degree from 90 to 125 knots and 0.1 degree from 125 knots to Mach 3.0 at sea level and its accuracy is 0.25 degree from 90 to 125 knots and 0.2 degree from 125 knots to Mach 3.0 at sea level.

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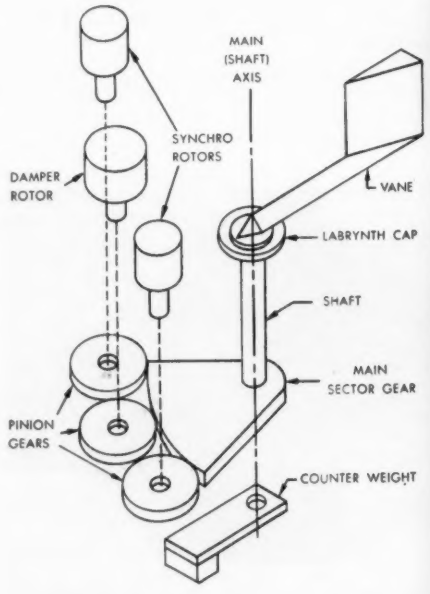


Schematic illustrates orientation of rotating members in the angle-of-attack unit. The heated vane is geared to output synchro rotors through a shaft vane sector gear and pinion gears. A 50 degree angular change of the vane element corresponds to 135 degree rotation of both synchros. The unit is designed to use potentiometer pickoffs, if required.

Advanced

INSTRUMENTATION

PROVEN DESIGN STANDARDS

CUSTOM ENGINEERED SPECIALS

ELECTRONIC TACHOMETERS and FREQUENCY COUNTERS

1280

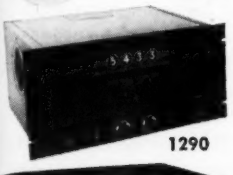
REMOTE AND EXPLOSION-PROOF *In-Line Numerical Indication*

Model 1280: 4-digit readout. **Model 1281:** 5-digit readout. Designed for operation of remote in-line readout at distances up to 500 feet. • Choice of indicator styles • Digital Count Down Time Base • Sine Wave: 5 to 150,000 CPS • Pulses: 0 to 150,000 CPS • ± One Count • Display Time: Adjustable from .1 to 10 seconds • Time Bases: .1, .5 and 1.0 seconds (Special time bases available) • Sensitivity: 50 MV RMS (5 MV optional) • Input Impedance: 1 megohm and 50 MMF • Electronically regulated power supply.

Standard or Explosion-proof housing.

SELF-CONTAINED *In-Line Numerical Indication*

Model 1290: 4-digit readout. **Model 1291:** 5-digit readout. Designed for dependable and precise readout of speed, frequency or flow. Same technical specifications as 1280 Series above excepting has self-contained readout.



1290

DECADE SCALER TYPE *Remote and Explosion-Proof (Class 1, Group D)*

Also Available With Self-Contained Indication. **Model 1260:** 4-decade, 60 cycle time base. RPM to 10,000 in one-RPM increments. Counts from 20 to 40,000 cycles per second ± .1%. (Available as Model 1270 with self-contained indication.)

Model 1261: 5-decade, 60 cycle time base. RPM to 100,000 in one-RPM increments. Counts from 20 to 100,000 cycles per second. ± .1%. (Available as Model 1271 with self-contained indication.)

Model 1262: 4-decade, 1000 cycle precision tuning fork time base, ± 1 count. Also available with odd-frequency tuning forks. Other technical specifications same as Model 1260. (Available as Model 1272 with self-contained indication.)

Model 1263: 5-decade, 1000 cycle precision tuning fork time base, ± 1 count. Also available with odd-frequency tuning forks. Other technical specifications same as Model 1261. (Available as Model 1273 with self-contained indication.) Suitable explosion-proof pickups are available. See Tachometer Pickup listings on this page.

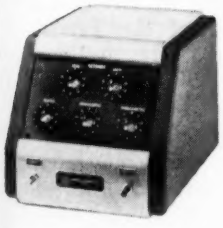
4150

PRE-SET COUNTER *For Automatic Control*

Model 4150: Designed for high speed counting and control in automatic operations. Panel switch permits use as totalizing counter at rates up to 5000 per second. Optional batch counter, (5-digit register) shown. Totalizes batches at rates up to 600 per minute. Various magnetic and photo-electric pickups can be furnished. Useable as preset time interval generator in 1/60 second increments for accurate timing of welders, processes, etc.

ELECTRIC TACHOMETER INDICATOR

***Model 635:** 6-inch dial. **Model 335:** 3-inch dial. *Designed as a precision, sensitive type electric magnetic-drag tachometer indicator assembly. Aircaft type movement provides great accuracy over wide temperature and speed range and within limits suitable to most lab requirements. The large pointer makes 3½ revolutions for full scale deflection (a total scale length of 66 inches). Suitable generators are available . . . see "Pick-ups" below.



C99F2

ELECTRIC *Glow-Transfer* MILLISECOND TIMER

Model C99F2: Designed to fill today's need for precise, reliable and convenient measurement of elapsed time. Available in 3 mounting styles: Console cabinet shown; flush panel mounted cabinet; explosion-proof housing. Complete timer is self-contained. Needs no external source of frequency control. Time base is 1000 cycle precision tuning fork. Count is displayed opposite numbers around periphery of glow transfer type decimal counting tubes. Timer can be controlled manually or by external means. Range: 99.999 seconds in .001 second increments. ± .001 second or .008%.

TACHOMETER PICK-UPS

All I-L-S tachometer pick-ups are designed to meet the rugged requirements of industrial service. The following are the most popular models.

635

Model 2000AG: UL Class 1, Group D explosion-proof impulse generator with tandem facility for auxiliary generator to provide pointer indication or analog signaling concurrent with digital information. **Model 2020:** Identical mechanism to Model 2000AG except foot-mounted for non-hazardous installations. Auxiliary generator mounting pad meets AND20005 spec.

Model 2060: Rugged compact unit for UL Class 1, Group D service where space is limited and signal requirements are for digital information only. **Model 2050:** Identical mechanism to Model 2060 except foot-mounted for non-hazardous installations. Standard frequencies are 60 to 120 impulses per revolution. Special frequencies available.

Model 2010: Explosion-proof drive and housing for AN5544-3 and AN5531-1 3-phase tachometer generators. 2 or 4 poles available to accommodate various drive ratios. Ideal for I-L-S 635 or 335 tach indicators.

Model 2030: Foot mounted drive assemble for AN5544-3 tach generator. Various other types of generatôrs may be adapted to the AND20005 mounting pad. Heavy duty ball bearing drive assembly.

Model 2040: Explosion-proof, pad mount to standard AND20005 engine tach drive pad. Standard 60 or 120 cycles per rev. Specials available.

Model 2043: Precision dual-pad impulse generator for "sandwich" mount between tachometer generator and engine AND20005 mounting pad on recriprocating or turbine engines. Frequencies 60 or 120 cycles.

Model 2CM9AAC: AN5544-3 tach generator available with 2 or 4 poles for powering I-L-S Model 335 or 635 tach indicator. Pad mounts to AND20005 mounting.

2060

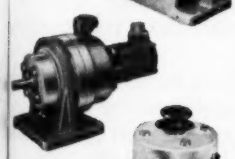
VARIABLE AUTOFORMER *Explosion-Proof*

Model 6240: Designed for panel mounting in hazardous areas where power line voltage control is required. Compact, lightweight, cast aluminum. Normally supplied with a Superior Electric type 116 powerstat. Rheostats and potentionmeters can be furnished on special request. Two smaller models with lower power ratings also available.

EXPLOSION-PROOF HOUSINGS

A wide variety of explosion-proof housings designed for Class 1, Group D service is available. These housings have successfully passed explosion-proof tests as conducted and certified by Inland Testing Laboratories of Chicago.

2020



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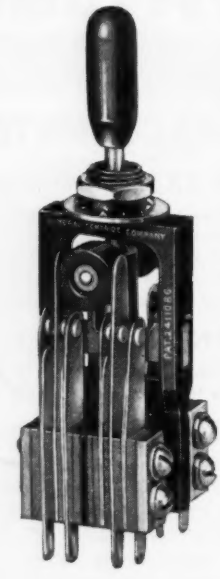

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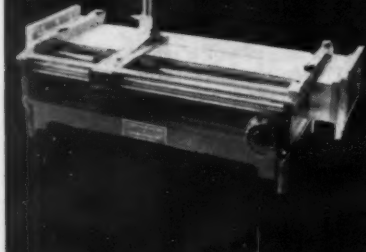

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PERSISTOR

Bi-metallic Printed Circuit for Switching and Signal Storage

Low temperature physics research has resulted in the development of a very high speed computer memory element which makes use of low temperature superconductivity principles to achieve both storage of information and instantaneous switching. The newly-developed device, trademarked "Persistor", is a miniature bi-metallic printed circuit which operates at a temperature within a few degrees of absolute zero (−459.6F). It requires very little power for operation and has been designed with switching times as short as 10 milli-microseconds (1/100 millionth of a second).

Designed for use in the memory unit of an electronic computer, the Persistor improves the access time to the memory 10 to 100 times over present methods. This increase in speed permits an improvement in balance between the arithmetic and memory units in the computer. The Persistor was developed in the Ramo-Wooldridge Aeronautical Research Laboratory, headed by Dr. Milton U. Clauser. Inventor of the Persistor is Dr. E. C. Crittenden, Jr., and research on the project was carried out by Dr. Crittenden and Dr. F. W. Schmidlin.

The new unit makes use of the superconductivity phenomenon exhibited by various metals at low temperatures to achieve both the switching and signal storage functions required of a computer memory element. Essentially, the Persistor is a loop composed of segments of two metals both of which are maintained in the superconductive state at a very low temperature. One segment of the loop is of a metal so chosen that the passage of a small current through it (the critical amount depending on its temperature) causes it to change from its superconductive to its normal resistance state. A subcritical current is induced in this loop and continuously circulates around it for an indefinitely long period; the direction of the current represents the information being stored.

Direction of the current in the loop is determined at any time by impressing an interrogating current pulse on the loop. The direction of the current in the Persistor is clearly indicated by the presence of a voltage pulse upon interrogation.

"Maintaining the low temperatures required for Persistor operation offers no obstacle to their immediate use in computers," Dr. Clauser says, "Recent advances in helium liquefiers make it feasible to maintain low temperatures at a cost which can be considered a negligible part of the cost of operation of a computer." Half a million Persistors will be able to operate in the space of only one cubic foot in a computer.

Dr. Clauser said that the company intends to continue its research into low temperature physics. He said that the success achieved in developing the Persistor leads Ramo-Wooldridge scientists to believe that other superconducting components can be developed which offer possibilities comparable in scope to those opened by the development of semiconductors.

Circle No. 212 on Inquiry Card

WORTH FILING

Integrating Amplifier

7-page bulletin describes the design performance and applications of a new four-tube electronic integrator with long memory, high sensitivity, excellent stability, and versatility. The amplifier can be used in computers and other electronic devices to integrate video, narrow pulses or intermittently sampled data and to provide long-term memory of integrated input information. Numerous circuit points of the amplifier are available at the terminals, increasing the versatility of the unit. Critical circuits are hermetically sealed, and all components are selected for accuracy and long life.

Source: Airborne Instruments Lab. Mineola, New York

For your copy: Circle No. 209 on Inquiry Card

WORTH FILING

Welding Data Book

180-page 1958 edition of the pocket-sized Welding Data Book describes simplified welding procedures for **every base metal.** The book, covering 120 welding rods, electrodes and welding compounds, is a guide to improved torch and metallic-arc welding, brazing and soldering. Useful "how-to-weld" information is given for fabrication, maintenance repair and salvage, overlaying for wear and corrosion resistance, and welding of dirty, rusted parts. Special welding applications such as joints with high electrical conductivity, tinning and plating are covered. Hundreds of applications for welding are given for every industry.

Source: Eutectic Welding Alloys Corp., Flushing, N. Y.

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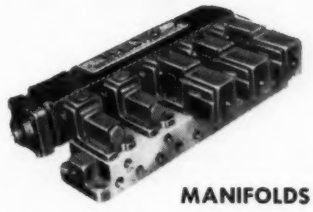

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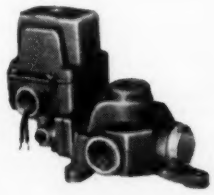

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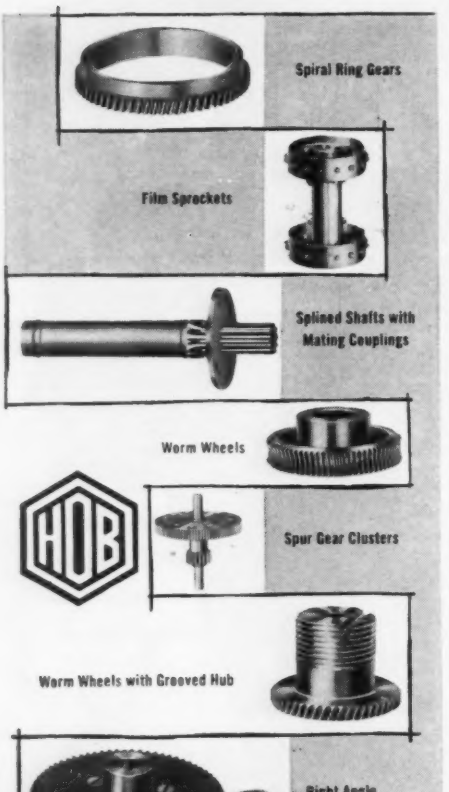

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CIRCLE 33 ON INQUIRY CARD

SALT WATER PUMP

No Seal is a Good Seal

Using a new design approach and an unconventional selection of material, Longport Marine Co., Longport, N. J., has developed a bilge pump that avoids the three most common faults in salt-water pumps.

The Lovett bilge pump uses insulating, non-corrosive Plexiglas in its major components to eliminate electrolysis induced by minute leakage of current from motor windings and insulation. It also has a permanent, maintenance-free air lock-seal which operates on the same "trapped-air" principle as that of an air pocket trapped in a tumbler inverted in water. This air lock prevents water leakage into the motor compartment and eliminates shaft seizure due to seals being shrunken or dried during prolonged idle periods.

MATERIALS SELECTION PROBLEM

The rapid destruction of exposed metal parts by electrolysis is the chief cause of deterioration in conventional bronze marine pumps. Lovett designers avoided this problem by using Plexiglas for the major components—the outer casing for the pump and motor assembly, the casing cover, the impeller and impeller housing and the outlet port (Fig. 2).

Besides being inherently non-corrosive, Plexiglas plastic is an excellent insulator, having a dielectric strength of about 500 volts/mil, and a volume resistivity of about 3×10^{17} ohm-cm. These insulating properties make it possible to eliminate the common problem of induced electrolysis. The pump motor is completely encased in an all-plastic compartment shielding the adjacent metal pump parts from possible stray-current leakage. The motor is further isolated by using laminated plastic pulley wheels and Buna rubber drive belts between the motor and impeller shafts.

The acrylic plastic provides lifetime freedom from corrosion and excellent resistance to chemicals, oil and grease. It does not discolor and retains its dimensional stability after months of continuous immersion in salt water. It also has high impact strength even in relatively thin sections, and will not dent. Thicknesses of the parts range from 3/16 in. for the flange on the casing to 1/16 in. for the impeller. Lovett engineers got permanent, maintenance-free sealing with a novel air lock. As shown in Fig. 1 the compartment through which the impeller shaft and electrical power cable pass is open at the bottom. With the gasketed acrylic plastic cover in place the upper end of this compartment is closed off to form the air lock. Although the bottom of the compartment is completely open to the water, the water cannot rise appreciably because the air trapped above the water resists compression. In short, the volume of trapped air acts as a seal.

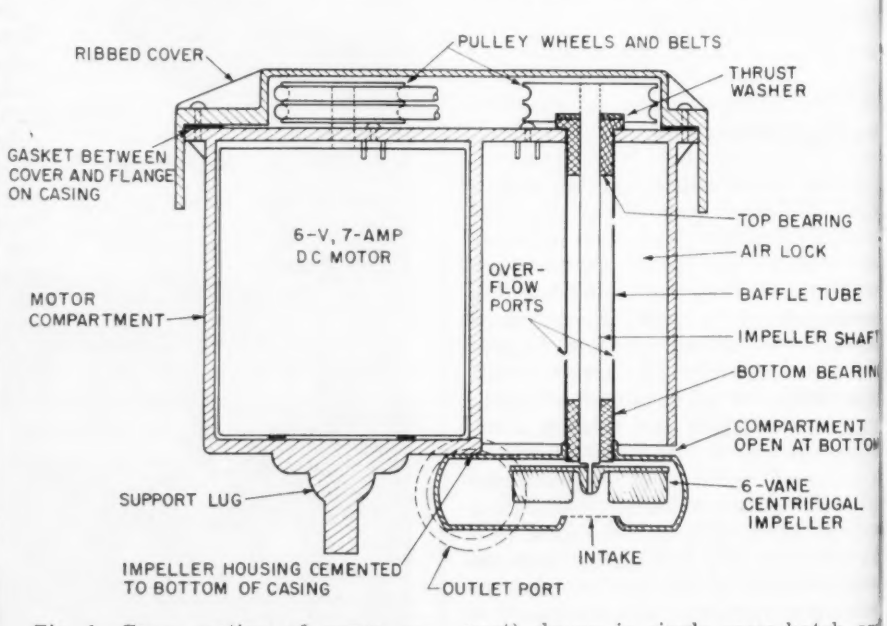

Fig. 1—Cross section of pump assembly showing motor and air lock compartments. All parts (plus outlet port) drawn in single cross-hatch are molded from Plexiglas.

Fig. 2—Exploded view showing the major parts of the Plexiglas pump. Mesh screen fits around pump to prevent solid materials from being drawn into impeller.

Of course, if the pump is submerged to sufficient depth, the water pressure will force the trapped air through the gasketing to flood the motor compartment. However, this will not occur until the pump is submerged to a depth of almost 30 feet. Under these circumstances the question of whether the pump is still operating would be the least of the boat owner's problems.

SHAFT SEIZURE ON START-UP

Since the air lock eliminates conventional seals and packing, the problem of shaft seizure because of shrunken or dried seals after prolonged idle periods is eliminated. In the Lovett pump, the impeller shaft rotates in Olite bearings (Fig. 1). The top bearings is press fitted to a depth of 1/2 in. into the brass impeller baffle tube which keeps the bearing cool by conducting away frictional heat. A stainless steel thrust washer rides between the top of the bearing and the bottom of the phenolic pulley wheel. The pulley wheel is press fitted on to the end of the impeller shaft knurled to provide maximum gripping action.

The lower shaft bearing is also pressed into the end of the baffle tube. The lower end of this tube is positioned and supported by being threaded into a collar on the upper half of the impeller housing which, in turn, is solvent cemented to the underside of the Plexiglas casing. The impeller is designed to force water between the impeller shaft and the lower bearing and cools the bearing whenever the pump is operating. The water forced up through the bearing is vented through a set of ports drilled about one inch from the bottom of the baffle tube. An additional port is located near the top of the baffle tube for overflow relief, in case the water ever rises to that level.

Circle 130 on Reader Inquiry Card.

New servo-controlled "Tilt Table" for missile guidance testing

This Thompson-engineered mobile unit aids in the functional check of an intercontinental missile's internal guidance gyroscopes. It generates angular position and velocity inputs to the gyros. Unit consists of electro-mechanical assembly, electronic pre-amplifiers and pick-off amplifiers, and quadrature rejection unit. Two-gimbled support structure will carry a 125-lb. guidance package.

New Actuator operates for 100 hours at 550°F submerged in jet fuel

Pictured is a new Thompson-developed actuator used in missiles. It consists of motor, gearing, feed-back pick-off and jacket. Unit has been tested for 100 hours of operation at 550°F submerged in jet fuel. Power output is 10 watts (mechanical). Torque output is 150 inch-ounces at 30 rpm at 550°F. Servo performance in conjunction with a computor produces a positional accuracy of ±½ degree. Approximate size: 3″ diameter x 4″.

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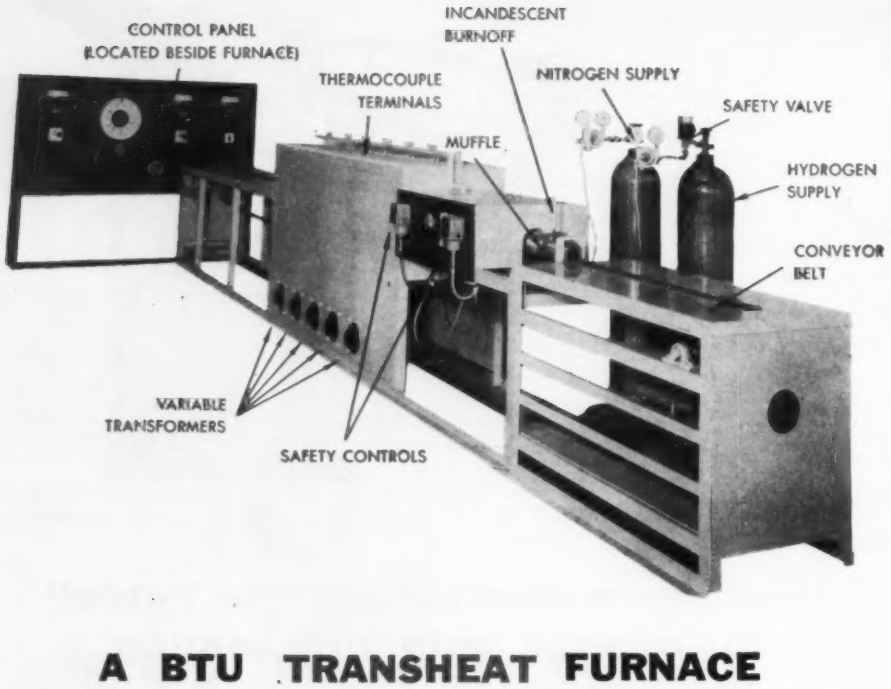

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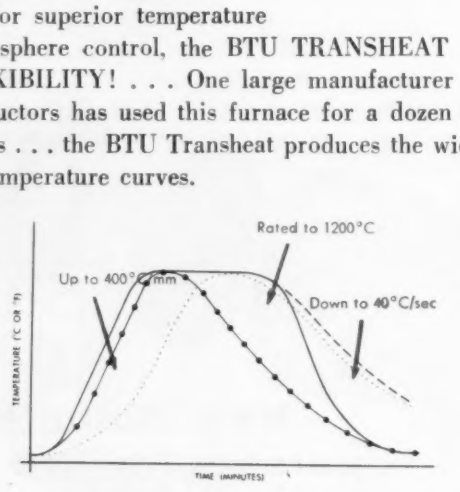

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Miniature Limit Stop

A new multiturn, adjustable limit stop, 0.87 inches in diameter, has a single range-setting screw at the end cap capable of adjusting stop rotation from zero to full scale continuously and with precision. Designed for the servo and instrument industries, this synchro mounted stop has torque capacity of 40 ounce-inches, low inertia, low starting friction, large turns capacity and capability for high speed application. Precision Mechanisms Corp., East Meadow, N.Y.

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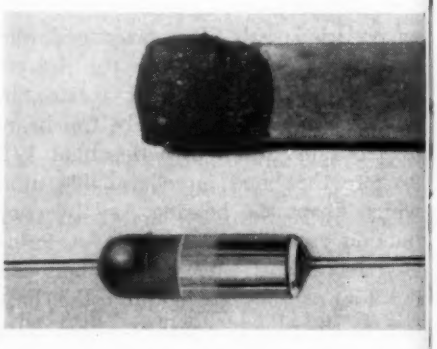

Wire Tantalum Capacitors

Primarily designed for low voltage DC applications such as transistorized audio amplifiers, these wire tantalum capacitors are extremely small with an operating temperature range of −20 C to +50 C and with adequate storage life. Satisfactory performance above 50 C is possible where shortened capacitor life can be tolerated. Of polar construction, the capacitor case and the attached lead form the cathode terminal and are available in insulated and non-insulated construction. The anode tantalum wire extends through the teflon bushing to which a solderable lead is attached. The welded connection is encapsulated in a thermosetting resin. All units are color-coded to indicate capacitance and voltage ratings. Aerovox Corp., New Bedford, Mass.

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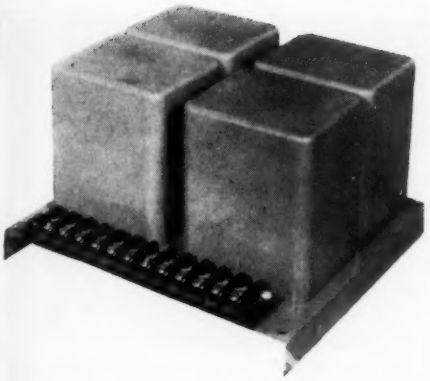

Safety Control for Presses

An anti-repeat press control with no moving parts uses magnetic amplifiers, diodes, a transistor, and a pulse transformer instead of relays. Operating on 115 volt a-c power, it receives input signals from the press "run," "stop" and "inch" buttons and the press limit switches, and delivers its output to the magnet of a protector air valve. Anti-repeat control prevents operation of the press unless safe conditions exist. Principal safety provisions of the new unit are: All "run" buttons must be depressed before a press stroke can begin and must be held down until the press downstroke is nearly completed. "Run" buttons must be released and depressed again before a new stroke can begin; if "run" buttons are taped or jammed down the press will stop at the end of its cycle. "Run" and "stop" buttons are directly in the power circuit, on both sides of the line. Clark Controller Co., Cleveland, Ohio.

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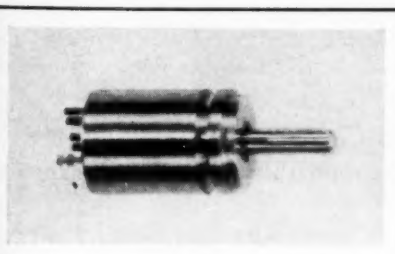

Hi-Temp, Single Turn Pots

New ½ inch, high-temperature, single-turn, stainless steel Helipot precision potentiometers, function over a temperature range of —55 degrees to +150 degrees C. Power rating above 5,000 ohms is 2.5 watts at 60 degrees C, derating to 1 watt at 150 degrees C; below 5,000 ohms, 1.5 watts at 60 degrees C, derating to zero at 150 degrees C. Standard resistance range is 500 to 70,000 ohms with a linearity tolerance of ±0.50 percent. Best practical linearity tolerance is ±0.25 percent. Three models are available, each weighing 0.3 ounces. Beckman/Helipot Corp., Newport Beach, California.

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CIRCLE 59 ON INQUIRY CARD

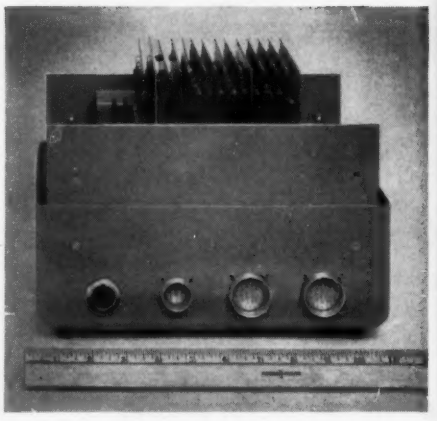
MACHINE TOOL POSITION CONTROL

A digital comparator has been designed to combine digital accuracy with conventional analog-servo techniques for automatic digital-to-analog positioning of machine tools or other equipment. It accepts any binary signal, compares it with a similarly presented feedback signal and produces an error-modulated a-c output.

Engineers at Norden Labs Division, Norden-Ketay Corp., Hawthorne, Calif., saw the need for a digital sensing servo both to complement their analog-to-digital converter and to provide positioning of machine tools from digital data. Total digit handling capacity of the comparator was set largely by the range and accuracy conditions of machine tool positioning requirements. Within these parameters the problem was to compare two digital numbers, arrive at the difference and convert the resulting number to analog voltage for the purpose of driving the system to null.

A design objective was extraction of the digital difference without using the large amount of equipment required to mechanize a digital subtractor or without introducing the problems of sampled servo systems using a serial subtractor.

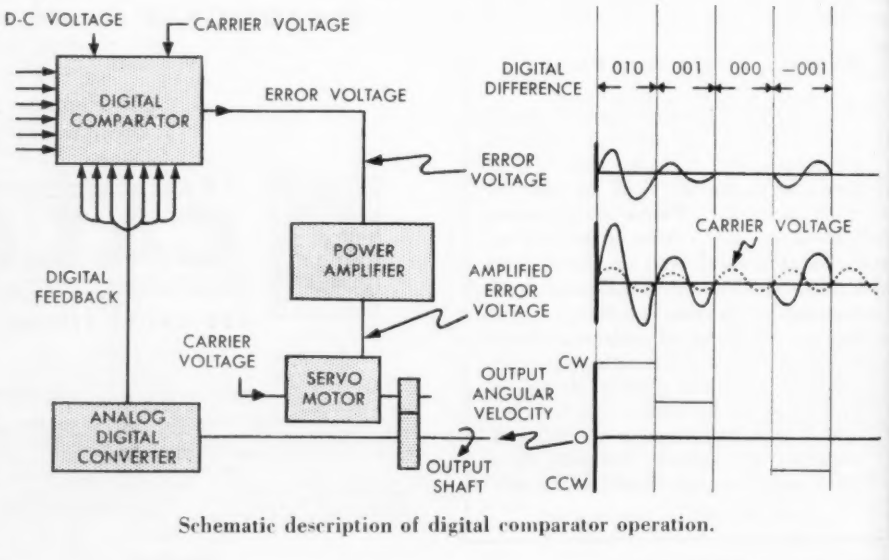
The designers recognized that a proportional output signal is only required in the region of the null. Accordingly, they designed a comparator that detects when the digital difference is outside or inside the null region and only subtracts, on a small number of bits, when the difference is inside the null region. With extremely minor modifications, this unit can be made to operate on binary-coded decimal data.



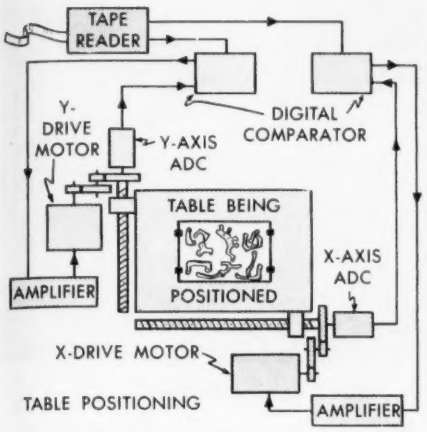
Photograph of Norden-Ketay packaged digital comparator with cover removed.

An alternative breadboard design was tried and rejected because, although it used fewer transistors, it demanded high tolerances on resistors and logical voltages. The design idea for this unit was to perform a parallel asynchronous digital subtraction and detect whether the answer is positive or negative as well as whether it is outside the null region. If outside, the full output signal of the proper polarity is provided. If inside, a properly polarized proportional output voltage is provided. In its final form this design became a binary device, but the logic for using it for decimal information has been developed.

In the final design, the comparator does not limit accuracy but can be made to arbitrary accuracy depending on the digital input. It has high and absolute accuracy over wide input range without any problems associated with drift of a reference voltage, and its frequency response is high enough for all reasonable application. Transistorized throughout and designed to



Schematic description of digital comparator operation.



Automatic drilling of printed circuit cards from tape-programmed instructions.

work with standard servo components, the comparator is small, light and packageable to fullfil aircraft physical and environmental specifications.

The comparator, which can be readily programmed from information stored on tape or cards, controls to one-bit accuracy over the complete range—for 19-bit information it controls to one part in 534,288. It eliminates drift tendencies of analog servo systems, counts numerically and provides absolute reference.

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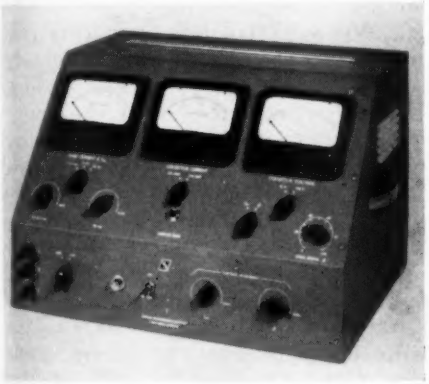

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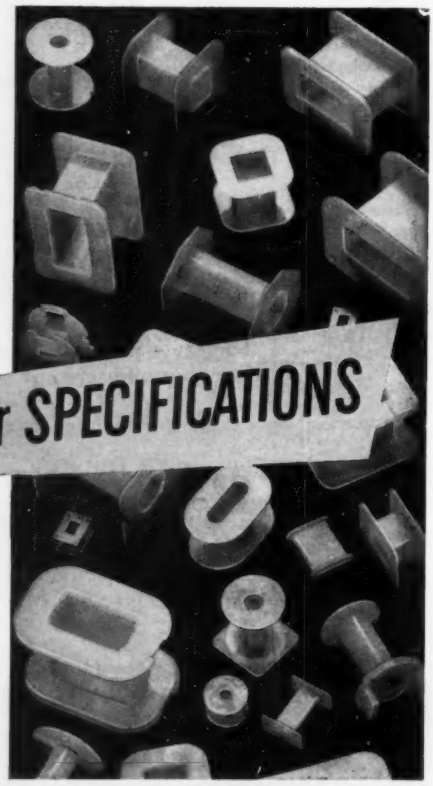

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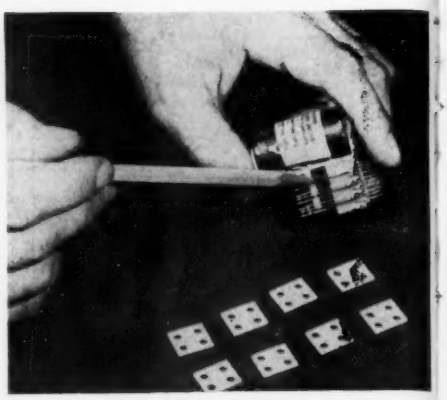

Spacers For Hot Relays

Use of a heat resistant laminate for relay spacer blocks has increased the operating temperature range of miniature relays and improved production methods. The laminate, designated as Phenolite G-7-830, is being used by Globe Electrical Manufacturing Co., Gardena, Cal., in their miniature, high-sensitivity sealed relays. This phenolite is a glass-base, silicone resin laminate specially developed for high temperature electrical applications. It has a heat resistance rating of 500°F (short time) and 400°F (continuous) —66 per cent and 60 per cent higher, respectively, than similar values for conventional paper-base laminates. Dielectric strength perpendicular to laminations is 400 volts/mil (short time) for 1/16 inch thicknesses and 350 volts/mil (short time) for ⅛ inch thickness. These properties in spacers permit relay operation at proportionately higher temperatures. Hermetic sealing of relays is facilitated by the extremely low volatility of the laminate spacers, since higher vacuums and temperatures can be applied without danger of gassing. The ability of the spacers to withstand higher temperatures makes possible a 30 to 50 per cent increase in coil ampere turns which provides greater sensitivity than conventional relays without appreciably increasing their size. Good punching qualities of the laminate have resulted in faster production. National Vulcanized Fibre Co., Wilmington 99, Delaware.

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WORTH FILING

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STAFF COLUMNIST

Ronald C. Vickery

Ronald C. Vickery is Head of Horizons Incorporated's Chemistry Department.

THE CHEMISTRY OF COMPONENTS

RARE EARTH SEMICONDUCTORS

Regardless of the type of semiconductor considered (reduction or normal), conductivity must depend largely upon the lattice symmetry and structure of the component crystalline phases. Periodic Group IV semiconductors (carbon, silicon, germanium and tin) each have the diamond-type lattice, the four nearest neighbors of a given atom lying at the corners of a regular tetrahedron, the neighbor-atom bonding being homopolar. By analogy the rare-earth metaloids may be presumed to have semi-conducting properties of some significance.

Studies on the semiconducting properties of elements other than those of group IV may be developed on the theory of "balance": that is, the properties of Group IV elements should be iterated by mixtures of Groups III and V, II and VI, etc. Crystallographically, lattice structure variations are also slight; thus, AlP, GaAs, InSb have the zincblende structure which is very close to the diamond structure—if the two types of atom were identical the diamond structure would be obtained. Further we find that Group IIIa elements with Group Vb elements (LnN, LnP, LnAs, etc.) have all the sodium chloride structure with four molecules in the unit cube—an even more fundamental lattice than that adopted by diamond and similar to the tetrahedral ZnS structure, also found in the interesting IV-VI Group compounds.

Since the sodium chloride structure of cubic symmetry is one of the most stable crystal forms known, it is expected that rare-earth metalloid systems adopting this structure will be both thermally and mechanically very stable. Intermetallic combinations giving cubic lattices are known to have higher critical homologous temperatures. We can therefore expect systems of rare-earth metals-metalloids to be of good thermal and mechanical stability. The varying atomic radii of the rare-earth metals should induce a sequential variation in these physical properties and a similar variation in the binding energies of the compounds formed. Higher binding energies, melting points and, consequently, stabilities should increase through the rare earths series.

Some correlation has been made between ionic radii, hetero/homopolar bonding and semiconduction properties, but the dearth of such data for rare-earth compounds militates against such a preliminary correlation. We can, however, draw some conclusions on the basis of melting points. Because of strong resonance, melting points of compounds are higher than those of corresponding elements. Similarly, the widths of forbidden zones are greater than in corresponding elements; since the ionic portion of the bonding increases in the transition from an element to a compound, the breadth of the forbidden zone must vary through the rare earths series.

However, in rare-earth sequences factors other than simple atomic radii and electron shell filling play important parts. By nature of these minor variants, anomalies are introduced immediately on consideration of the Hall effect in rare-earth metals. Thus cerium, praseodymium, and neodymium show positive Hall effects (+1.81, +0.709, +0.971, x 10^{-12} volt-cm/amp oersted); dyprosium is temperature variant; and yttrium, lanthanum, gadolinium, and erbium have negative coefficients (−0.77, −0.8, −0.95, −.341, x 10^{-12} volt-cm/amp oersted).

It has been suggested that a two-band theory is necessary for elucidation of rare-earth metal conductivity, conduction being by electrons in the 5d band and holes in the 6s band, with three electrons available for distribution —the 4f band contributing nothing. In the case of "condensed" cerium the assumption was made that four electrons were available because the 4f electron moved to the 5d and 6s bands. We can expect similar migration in terbium, samarium, europium, and ytterbium metals. By comparison, some dependence must be placed upon the 4f shell, since lanthanum—with no 4f electron—is the only superconductor in the rare-earth metal series.

POWER SOURCES: A NEW APPROACH

Without the help of radiation, visible or otherwise, electrons can be transferred in chemical reactions only from molecular species with the higher, to those with the lower, reduction potentials. In photo-synthesis, however, electrons are raised by the action of light from molecules with a reduction potential of −0.8 volt to molecules with a potential of +0.4 volt. A somewhat wider range of parameters obtains under γ radiation; but the problem generally lies, however, not so much in raising electrons to a higher potential as in keeping them there—that is, of course, most readily effected by removal of one of the reaction products from the system. One way this can be effected is by ensuring the escape of the product gas, and therein lies one of the approaches to use of solar energy—photo-decomposition of water to hydrogen and oxygen, followed by their subsequent exothermic recombination to yield water and usable energy. This reaction can also be applied to systems under a neutron, γ, or X-ray flux, with similar development as a means of energy conversion.

This gaseous-decomposition approach has recently been studied in systems of cerium perchlorates in dilute aqueous perchloric acid with the probable over-all reactions:

$$Ce^{4+} + (1/2)\ H_2O + \text{Light} \rightarrow Ce^{3+} + (1/4)\ O_2 + H^+$$
$$Ce^{3+} + H_2O + \text{Light} \rightarrow Ce^{4+} + (1/2)\ H_2 + OH^-$$
$$H^+ + OH^- \rightarrow H_2O$$

or

$$2_1Ce^{4+} + 2_2Ce^{3+} + H_2O \rightarrow 2_1Ce^{3+} + 2_2Ce^{4+} + H_2 + (1/2)\ O_2$$

the quantum efficiency of the reactions involved being independent of the light intensity but dependent upon the concentration of cerium ions.

Most of the work in this area has been carried out using ultraviolet light having a wavelength of 2537 Angstrom units, which is beyond the limit of the solar spectrum as it reaches the earth's surface. Some work has shown that reduction processes may be effected by several weeks' exposure to sunlight, but it is quite clear that quantum ef-

ficiencies of the system as now studied are too low for economic operation. Decomposition of water also occurs under γ radiation, and this is similarly catalyzed by cerium ions. It is logical to expect that, in applying γ radiation, the quantum efficiency of the reaction will be much higher. In general, what is to be sought is a photo-excited oxidation-reduction reaction of higher potential. This may be found in cerium-arsenic systems.

Cerium was, for a while, employed as a decolorizing agent for iron in glasses until it was found that, in the presence of arsenic, the cerium-decolorized glasses were rapidly "solarizable"—became discolored upon exposure to light. This discoloration disappeared if the glass were removed from light and stored in the dark.

Disregarding initially the influence of iron, we can visualize the reactions:

$$2\,Ce^{3+} + As^{5+} + (1/4)\,SiO_2 + \text{Light} \rightleftarrows 2\,Ce^{4+} + As^{3+} + (1/4)\,O_2 + (1/4)\,Si^{4+},$$

the ceric ion produced probably being colored and the liberated oxygen reacting with colorless ferrous ions to give ferric ions which were also colored.

Since in glasses the gaseous product, oxygen, cannot escape, reversal of the reaction is inevitable. If, however, we consider the same reaction in aqueous media:

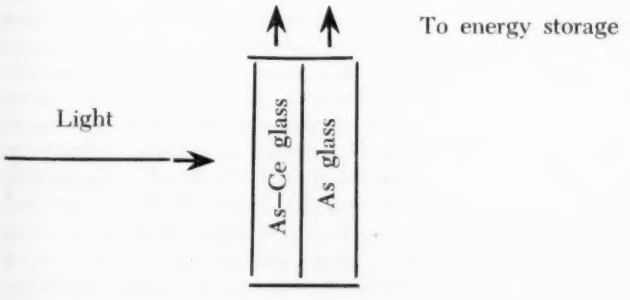
$$2\,Ce^{3+} + As^{5+} + (1/2)\,H_2O + \text{Light} \rightarrow 2\,Ce^{4+} + As^{3+} + (1/4)\,O_2 + H^+$$

$$2\,Ce^{4+} + As^{2+} + H_2O + \text{Light} \rightarrow 2\,Ce^{3+} + As^{5+} + (1/2)\,H_2 + OH^-$$

$$OH^- + H \rightarrow H_2O$$

High quantum efficiencies are to be expected of such a system, which would appear eminently suited for study as a potential medium for radiation energy utilization.

Carrying this concept a stage further, it is possible to visualize direct application of this solarization effect in solid systems via the development of an oxidation-reduction couple in the glass system, with photochemical production of electrical energy. Thus, assuming the production of metallic arsenic, as indicated above, to be valid, a couple could then be set up as shown:



As – As_2O_3 Couple

Theoretically such a couple should provide an emf on solarization of about 0.6 volt. Providing an adequate medium of contact could be devised, herein lies a potential method for the direct conversion of light to electrical energy similar to that using selenium photocells.

In his next column Dr. Vickery will report on potential and soon-to-come rare-earth applications in piezoelectric crystals and thermionics.

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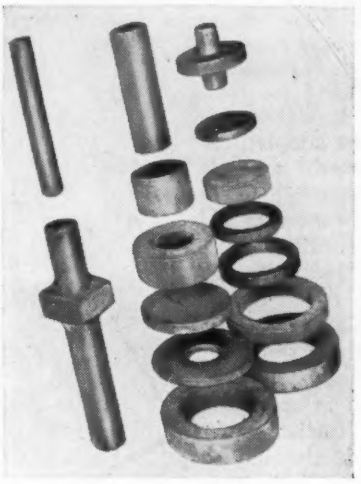

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MEDICAL ENGINEERING

Color TV in the Bio-Lab

Colored television has been adapted to portray "electronically stained," colored pictures of transparent living cells and other specimens. Many constituents of living cells, although practically transparent to visible light, have strong characteristic absorptions in the ultraviolet. The Television Color Translating Microscope projects three separate and successive pulsed light sources selected for high emission in specified wavelength ranges and further narrowed by monochromators through a specimen and microscope into the orthicon of an ultraviolet-sensitive television camera. It translates differences in absorption in separate ultraviolet spectral ranges into selected colors in the observed picture. Any primary color may be correlated with any wavelength in the ultraviolet. Figs. 1 and 2 illustrate the principles involved.

Frequently, detection of a particular substance with a characteristic transmission or absorption in the ultraviolet is of primary interest. This may be aided materially by slow periodic interruption of the corresponding source of illumination on the color channel. The presence of flicker then supports detection on the basis of color alone.

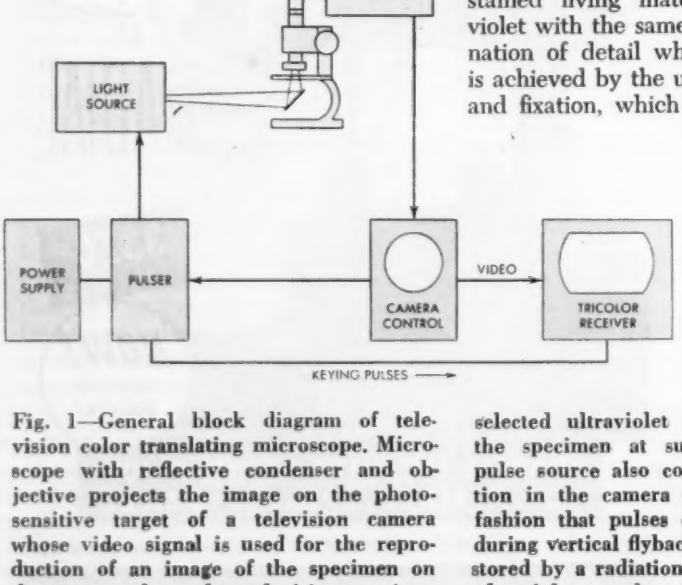


Fig. 1—General block diagram of television color translating microscope. Microscope with reflective condenser and objective projects the image on the photosensitive target of a television camera whose video signal is used for the reproduction of an image of the specimen on the screen of a color television receiver. Illumination is provided by one or several pulsed light sources and monochromators so arranged that radiation of the three selected ultraviolet wavelengths falls on the specimen at successive pulses. The pulse source also controls vertical deflection in the camera and receiver in such fashion that pulses of illumination occur during vertical flyback time. Picture signal stored by a radiation pulse of a particular ultraviolet wavelength is used for generating a component picture of the corresponding color in the succeeding frame period.

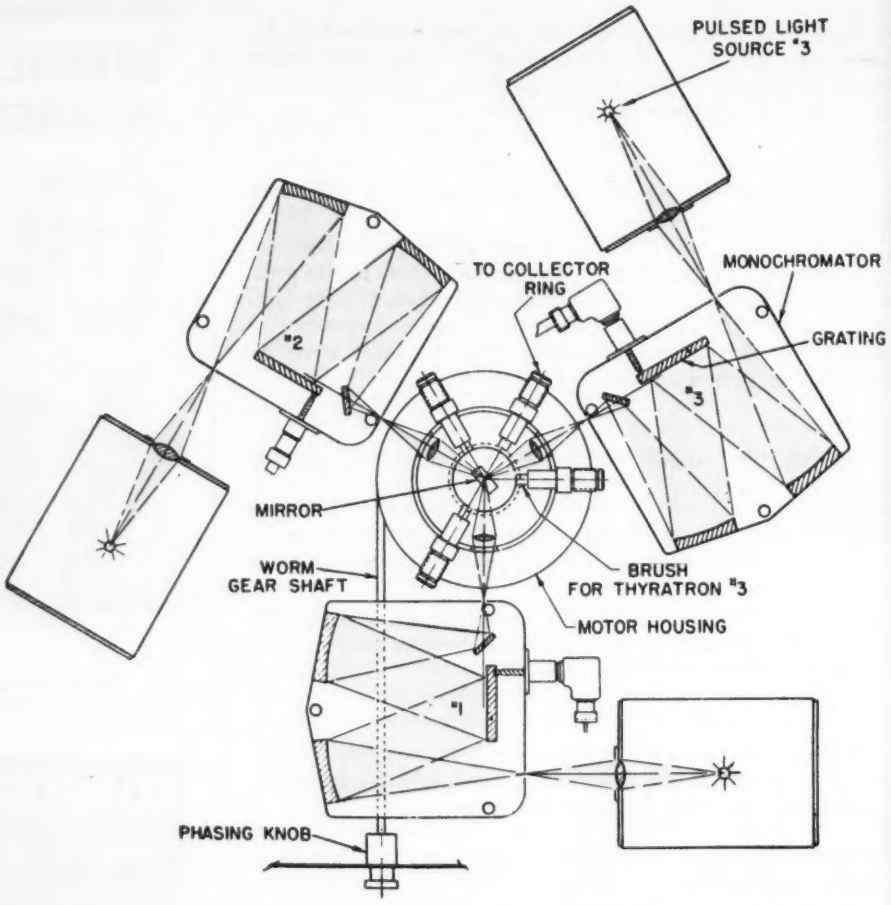


Fig. 2—Diagram of illuminating system. The source is imaged by a quartz lens on the entrance slit of the monochromator which narrows the wave band by means of an adjustable grating. Radiation from the exit slit is directed onto the center of rotation of a 45 degree mirror which reflects it up into the microscope substage.

V. K. Zworykin of Radio Corporation of America and Rockefeller Institute for Medical Research states: "The Television Color Translating Microscope makes it possible to examine unstained living material in the ultraviolet with the same ease and discrimination of detail which, in the visible, is achieved by the use of specific stains and fixation, which generally result in the death of the cells. It should prove not only a powerful tool in the study of vital processes in normal and abnormal cells and tissues, but may also become a valuable aid in diagnosis."

As background for this development, E. N. Brumberg suggested photographing specimens when illuminated, in succession, with radiation of three different ultraviolet wavelength ranges and using the three as separation negatives for preparing a color print. Photographic color translation mircoscopes based on this principle and using high-speed processing techniques have been built by E. H. Land and, more recently, by H. P. Hovnanian and R. B. Holt. In these instruments the final color picture is viewed on a screen, on which red, green, and blue images of the three separation negatives are projected in superposition.

In the first television color translating microscope, constructed several years ago at the RCA Laboratories in Princeton, a single pulsed light source and monochromator was used in conjunction with a standard industrial television camera provided with an experimental ultraviolet-sensitive vidicon. Fig. 4 shows the operation.

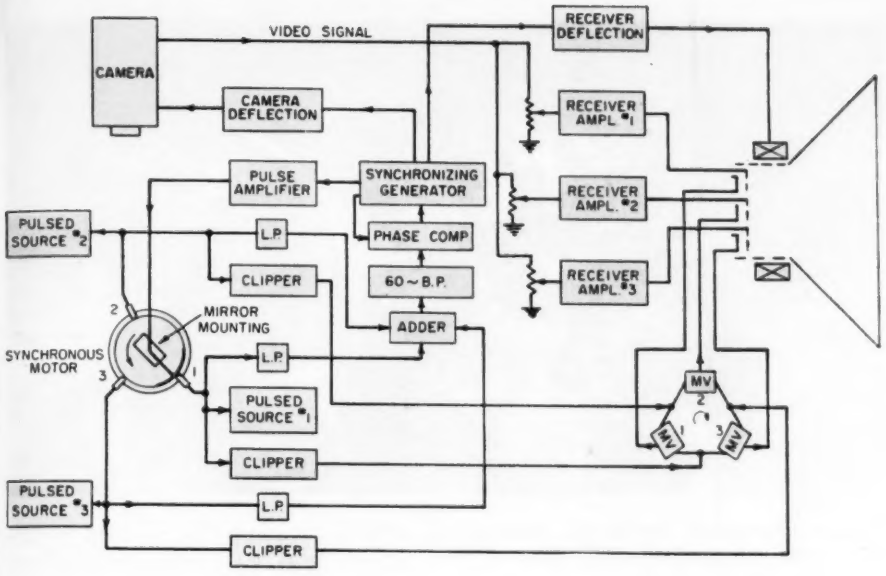


Fig. 3—Block diagram for color translating microscope at Rockefeller Institute. Amplified vertical pulses from the synchronizing generator of the television system are applied, through contact brushes on slip rings attached to the mirror stage, to the three thyratron circuits feeding the light sources in succession, triggering a light flash at the instant when the principal ray from the monochromator and the normal to the rotating mirror surface lie in a common vertical plane. Synchronism between the mirror rotation and the synchronizing generator is assured by the fact that a 60-cycle wave derived from the commutator controls the phase of the synchronizing generator. Synchronizing signal is generated from the output of the commutator and serves, at the same time, to pulse the several light sources and to gate, by means of a multivibrator circuit, the corresponding guns of the color kinescope.

While the principle of color translation could be readily demonstrated with this instrument, it had some shortcomings. Every change in wavelength required a new sector mirror. The lag of the experimental vidicon caused signal carry-over from one frame to the next, making it impossible to obtain highly saturated colors. The variation in the angle of incidence of the illumination with wavelength made it difficult to achieve color balance over the entire field. These shortcomings have been overcome in this latest design.

For the future, plans are being made to develop a new technique truly quantitative in its application. In this technique the relative concentration of substances with characteristic absorptions will be determined. A particular substance will be selected by a line-selector oscilloscope and the outputs for the red, green, and blue pictures, corresponding to the three selected ultraviolet wavelengths, will be represented on three separate oscilloscope screens. In order to render this technique truly quantitative, the illuminator optics will be made achromatic throughout and density step wedge calibration will be employed. The television color translating microscope will then become an instrument not only of observation, but also of quantitative measurement.

This design description was presented by V. K. Zworykin of Radio Corporation of America and Rockefeller Institute for Medical Research at WESCON, August, 1957.

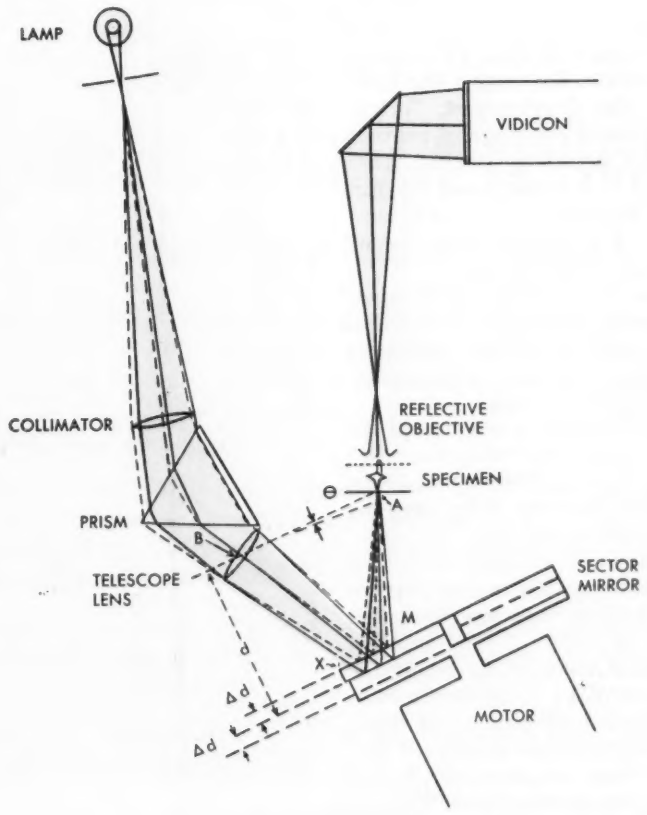


Fig. 4—Wavelength selection in single-source color translating microscope. A simple mechanical system was used to select in turn radiation of three different wavelength ranges for specimen illumination. Method of wavelength selection is based on the fact that the focal points for a prism monochromator with uncorrected colimator and telescope lenses made of the same material as the ionism lie along a straight line which is oblique to the direction of the reflected pencils. If the entrance slit of the microscope illuminator is placed on this straight line, a plane mirror perpendicular to the line will project the focal point for radiation of different wavelengths onto the slit as it is displaced in a direction perpendicular to its surface. In the instrument the plane mirror took the form of a disk consisting of three mirror sectors, recessed by a few tenths of an inch with respect to each other in correspondence with the three selected ultraviolet wavelengths. The sector disk was driven by a synchronous motor so phased with respect to the vertical deflection of the television system that the specimen was illuminated with the appropriate ultraviolet wavelength in the fly-back time preceding each color frame.

COMPUTER MEMORY

How to Store More Bits on a Drum

A major limiting factor to applications of electronic computers in business and science is the need for faster random access to large volumes of information at low storage cost. Engineers at Laboratory for Electronics, Inc., Boston, Mass., under the direction of Dr. Harrison Fuller, have developed a data storage unit which they believe fully satisfies this need. Any number of these units, with a capacity of 15 million binary bits each, can be connected to form a data file having an average random access time of 180 milliseconds for any information in any part of the file.

"Recognition of this need," said Sidney Woodsum of the LFE Applied Physics Group in discusssing the background for the development, "originated out of basic studies and research in the field of digital computing. When we launched the development program for a fast, 1000 bit per inch drum several years ago, it seemed to many that we were reaching for the moon."

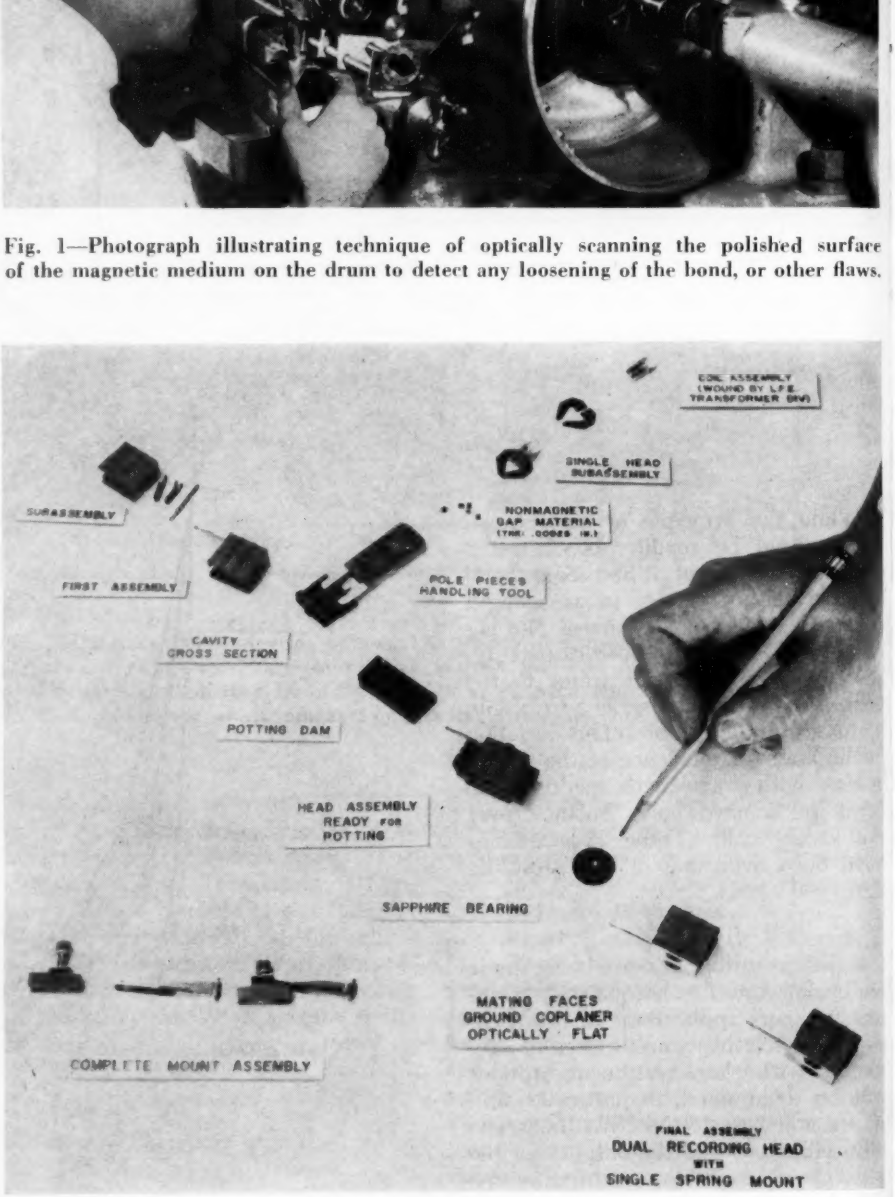
Analysis of the problem and a survey of the possible means for its solution led rather easily to a clear statement of the design objective. The reasoning was straight-forward:

- Punch-card storage was unacceptable because it was inherently too slow
- Magnetic tape mechanisms could not be considered because they were by nature not random devices
- A multiple-head magnetic drum met the speed and random access requirements and had no necessary limitation on capacity or low cost. The problem therefore became one of increasing the storage capacity of a magnetic drum at low cost. The simple answer of using more and bigger drums would not fulfill the low cost requirement. Boiled down, then, the problem was "How to get more, accessible bits on a drum."

DESIGN REQUIREMENTS

The basic ingredients in magnetic storage are a magnetic storage medium, a recording head, which is nothing but an electromagnet with a small air gap in its core adjacent to the magnetic medium, and some arrangement for moving the magnetic medium with respect to the head. For a given rate of travel of the magnetic medium, the higher the frequency of the recording, the shorter the wave length, and the

Fig. 1—Photograph illustrating technique of optically scanning the polished surface of the magnetic medium on the drum to detect any loosening of the bond, or other flaws.



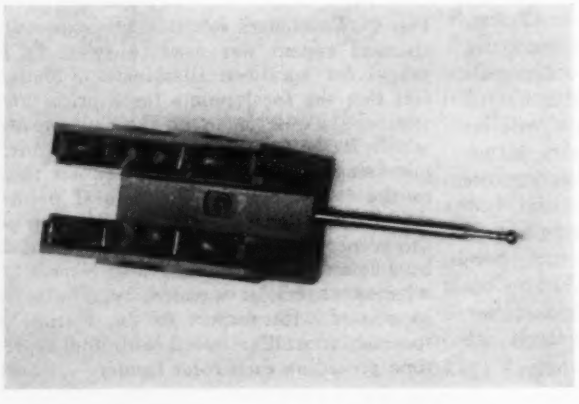


Fig. 2a—Exploded view of dual recording head and head mount.

Fig. 2b—View from above dual recording head showing jewel cup at center into which the head mount pivot presses to position and hold the head pin on the drum. The "tail" at left is used as a linkage with a mounting bar to prevent unit from rotating about the pivot axis in operation.

more bits per inch. Since fast access time required fast drum speed, high frequency recording was a design requirement.

During recording the magnetic flux spreads in the medium beyond the area directly beneath the head gap. At high bit packing densities, this spreading flux influences adjacent recordings and makes it difficult for the head to resolve discrete bits upon playback. Accordingly, maximum resolution of magnetic recording was a design requirement.

At the very outset of the development, the goal for storage density was 1000 bits per inch and the goal for average access time was better than 0.2 second. A 15-inch diameter, 14-inch-long aluminum drum cylinder available from a previous development was found to be well suited to the new design. Juggling the various parameters for the system using this drum, the designers established that a drum surface speed of 150 inches per second and a computer clock rate of 150 kilocycles would meet the requirements. The simple rim drive used in the earlier drum application was replaced with a timing belt drive powered by a hysteresis damped synchronous motor.

Performance of the final design eventually increased to a storage density of 1040 bits-per-inch and an average access time of 0.18 second.

RESOLUTION

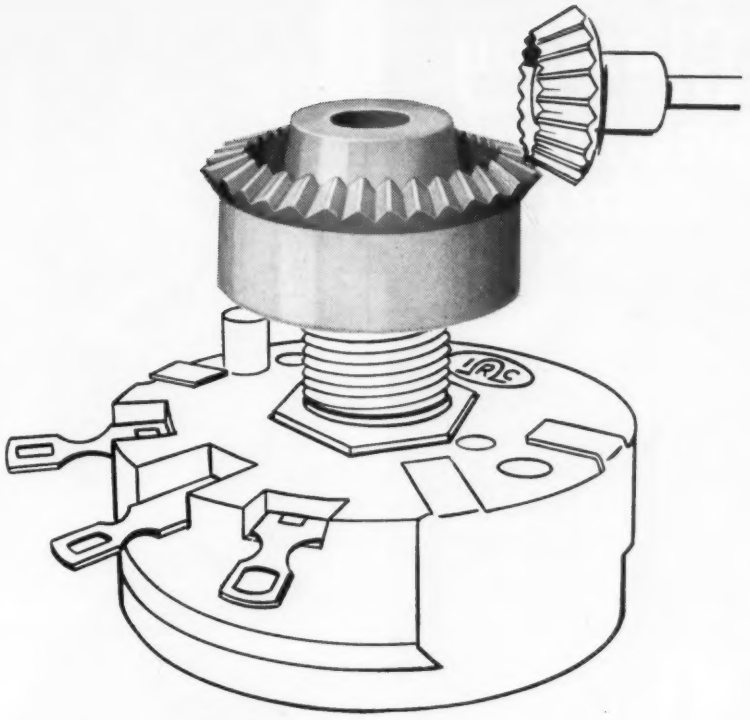
Three factors directly influence resolution of a magnetic recording:

- Magnetic medium. For short wavelength recordings, storage density of a magnetic medium increases as the ratio of coercivity H_c, to saturation induction, B_r
- Recording head. To minimize spreading of flux in a magnetic medium, recording head-gap length must be small compared to the shortest wavelength being recorded
- Head to medium separation. The spreading of the flux developed across the head gap increases with distance from the gap. The closer the head is to the medium, the more confined is the recording field.

As Mr. Woodsum said, "Optimizing these three parameters to obtain high bit packing densities was an interesting problem in electromechanical design." It can be seen that magnetic heads with small gaps riding directly in contact with a high coercive force medium would provide a system with the greatest possible pulse packing density.

MAGNETIC MEDIUM

Search for a suitable magnetic medium was a major problem in the



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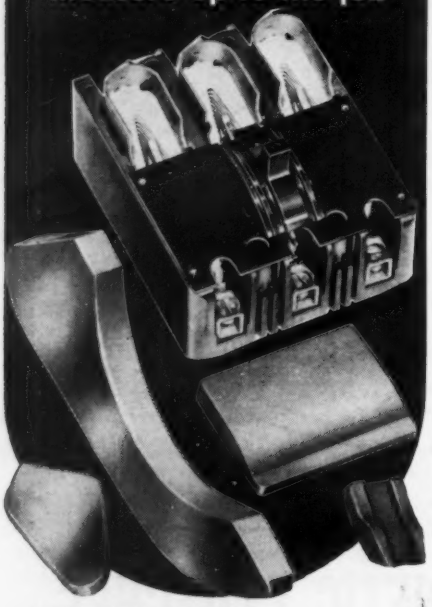

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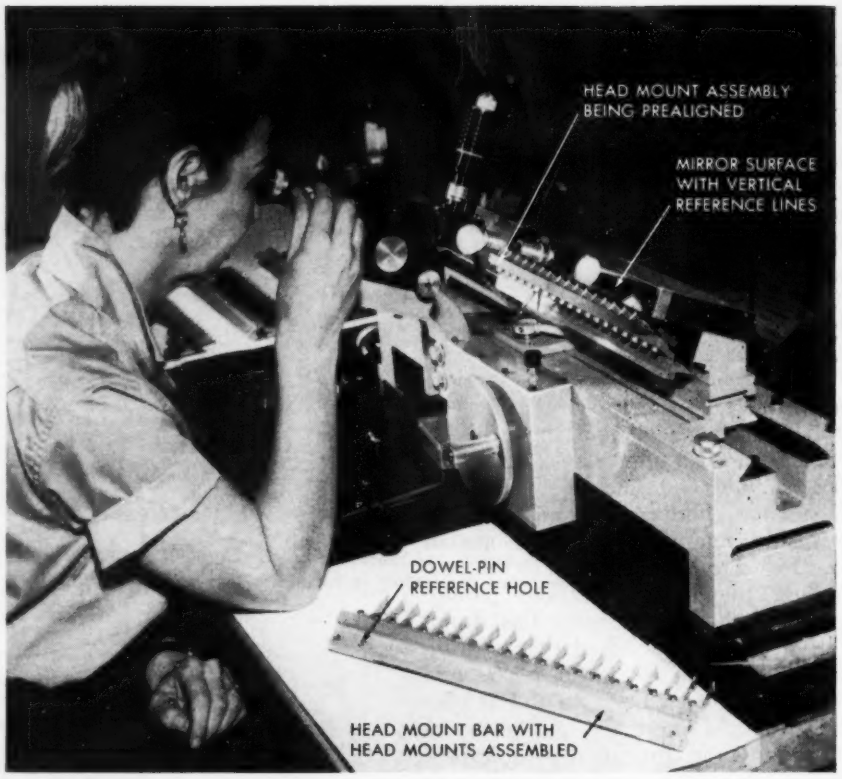
HEAD MOUNT ASSEMBLY BEING PREALIGNED
MIRROR SURFACE WITH VERTICAL REFERENCE LINES
DOWEL-PIN REFERENCE HOLE
HEAD MOUNT BAR WITH HEAD MOUNTS ASSEMBLED

Fig. 3—Photograph illustrating technique of prealigning head mounts on head mounting bar. The head mounts are optically prealigned in a precision fixture so that the relative positions of the pivots and a dowel pin locating hole are the same on each assembly.

early phases of the project. Conventional oxide coatings or thin electroplated magnetic coatings such as cobalt nickel were unsatisfactory if the heads were to be operated directly in contact. In addition, the coercive force of cobalt nickel was too low to provide resolution for short wave recordings. Rubber belts containing a high coercive force magnetic dispersion and a wax lubricant were used on the first drums. Successful recordings were made with up to 800 bits an inch using this medium but the mechanical instability of the rubber and its tendency to "washboard" removed it from serious consideration.

A radically new approach was needed to achieve the goal of over 1000 bits per inch. A survey of materials for the application resulted in the choice of Cunife wire, a permanent magnet ductile alloy of copper, nickel and iron. It met the magnetic requirements having a coercivity of 500 oersteds and a residual induction of 5400 gauss. Its physical hardness—Rockwell B-73 and tensile strength of 120 pounds per square inch—made it suitable to withstand wear from heads run in contact.

High coercivity of Cunife is achieved through cold reduction. As a result it is useful only in strip or wire form. The problem was, then, to obtain a continuous cylindrical surface using wire.

According to Robert Pearson, in recalling some of the mechanical difficulties in design of the magnetic medium, three years were required to solve all of the aspects of this problem. The only Cunife wire available originally was circular in cross section. It was wound under tension on the drum cylinder and then ground to half its diameter. Internal stresses of the wire caused an occasional turn to rotate axially. Resultant lifting of the wire edge, although only a few millionths of an inch, caused very rapid destruction of the head operating on that track. This problem was solved by bonding the wire to the drum cylinder.

Search for a suitable bonding agent was successful at about the time the wire manufacturer was persuaded to develop a die for drawing rectangular cross section wire. A technique of rolling and slitting the Cunife material to obtain a rectangular cross section had been considered but rejected because Cunife fabricated that way did not have the high coercivity required. Even though rectangular wire was used, the bonding technique was retained to insure no movement of the wire.

Spring loaded recording heads riding directly in contact with the drum sur-

face eliminated the difficulty of maintaining drum concentricity within any strict limits. The problem of drum surface finish however turned out to be imposing. Even with most careful winding, burrs arose at the wire edges causing excessive head wear. Boundary lubrication of the recording heads by means of a thin film of oil on the drum surface did not overcome this wear sufficiently. Parallel programs to improve drum surface finish and lubrication techniques resulted in use of optical lapping and hydrodynamic lubrication. Optical lapping now produces a drum surface with better than one microinch-rms finish and no burrs at the wire edges (Fig. 1). Hydrodynamic lubrication is discussed later as the method used to maintain separation between the recording head and the magnetic medium.

MAGNETIC HEAD

Conventional magnetic recording heads with metallic laminated pole pieces, such as Molybdenum permaloy, could not be used in a high density storage system for a number of reasons. Losses in metallic heads are large at a frequency of 100 kilocycles. In addi-

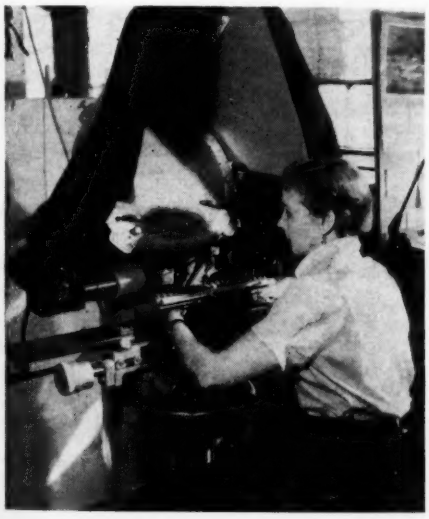

Fig. 4—Photograph illustrating shadograph technique of preadjusting pressure of pivots on recording heads. A head mounting bar with head mounts assembled and prealigned is shown being adjusted. The pivot-mount springs in the head mounts are loaded and adjusted to have the same deflection they would have under operating conditions, thus assuring each head will be under the same prescribed pressure. This prealignment technique makes it possible to substitute any head mounting assembly for any other with no change in performance of the system.

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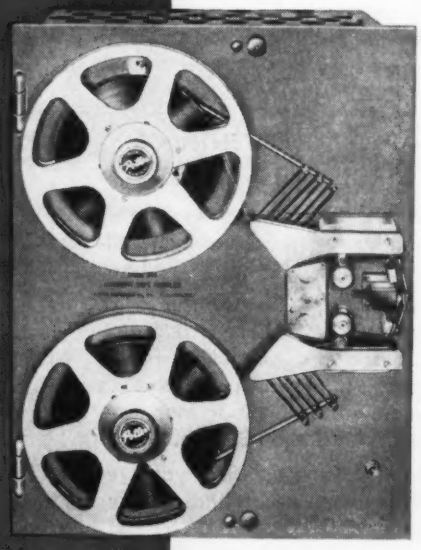

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CIRCLE 48 ON INQUIRY CARD

tion, even with direct contact between the heads and magnetic medium, effective separation exists partly as a result of finite surface roughness of the medium and to a greater extent because of a layer of material with low permeability at the surface of the head itself. This layer results not only from grinding the pole piece during fabrication but also from cold working as the head rides in contact with the drum. A magnetic head with ferrite pole pieces was the alternative; but such heads with small well-defined gaps were unavailable commercially. A program to develop heads with ferrite pole pieces was therefore necessary.

The one-mil wave-length specification required that the recording head gap be approximately 300 microinches. The rough finish on the mating surfaces of stock ferrite pole pieces made dependable gaps of that magnitude impossible. Here again optical lapping techniques and rather elaborate holding fixtures made possible highly polished pole-piece faces, coplanar to within one wavelength of helium light. A Beryllium copper spacer 250 ± 10 microinches thick is used in the gap.

The first head packages used on early experimental drums were ⅛ inch thick and approximately ⅝ inch square. They were positioned and held against

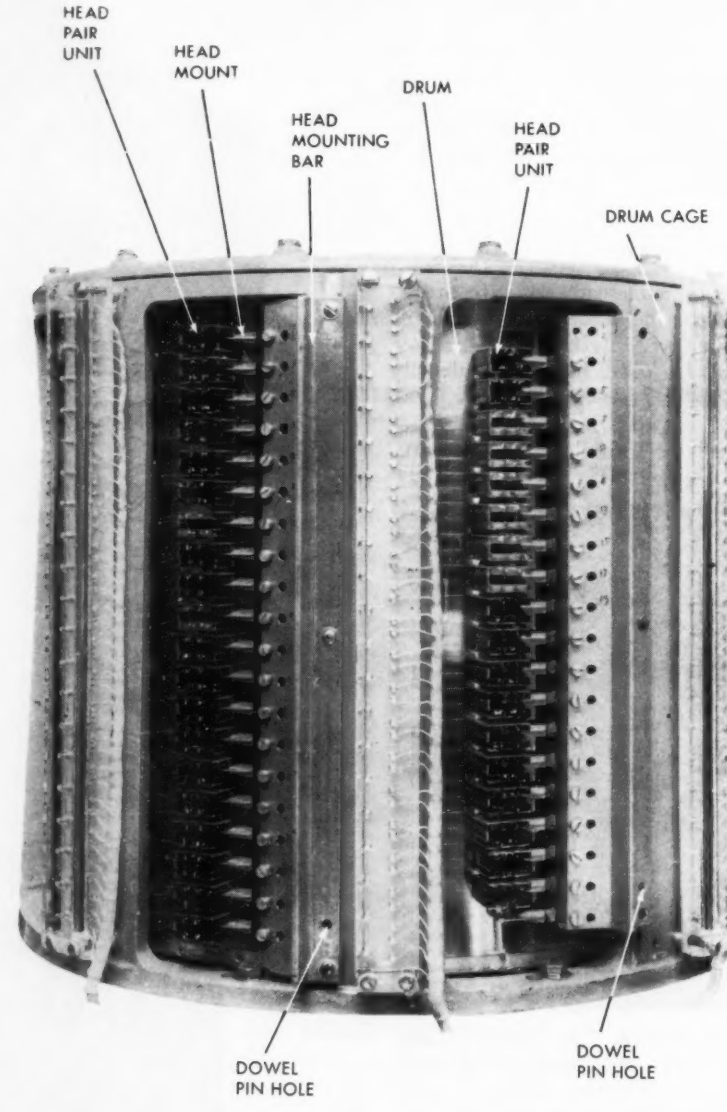

Fig. 5—Photograph of high density file drum with oil-tight aluminum housing removed to show mounting of magnetic heads. Each head pair is positioned and held against the drum by a spring loaded pivot pressing into a sapphire cup jewel near the center of the head package. The double heads are mounted in rows of 20 in each of eight windows in the drum cage. The pivots for each row are at the ends of parallel head-mount arms extending from a head mounting bar at one side of the window. Position of the mounting bar at the side of each window is determined by an accurately indexed dowel pin in the drum cage. The dowel pins are so located from window to window that each head pair is on different tracks from those of all the others. The resulting twenty pairs of tracks in each of eight windows make 320 separate tracks separated 0.040 inches center-to-center.

the drum surface by a double-spring head mounting device.

"After the development of hydrodynamic lubrication," said William Gorman, in discussing the problems in designing the heads, "an entirely new concept in head mounting was possible." The new heads were assembled in pairs and encapsulated in a magnesium casting. They were designed so that each head pair is positioned and held against the drum by a spring loaded steel pivot pressing into a sapphire cup jewel located near the center of the head package (Fig. 2).

Optical lapping again was used to make the two operating faces that ride on the drum coplanar to one wavelength of helium light. Each head face was made 0.030 inch wide by 0.200 inch long with the gap at the center. Accurate machining of these castings and special holding tools and fixtures for positioning the ferrite and coil bobbin subassemblies made production line assembly of the heads possible. Another special fixture was used to accurately position the cup jewel in a pocket in the head casting. The jewel was then secured with a metal filled epoxy cement.

The close tolerances held throughout this head assembly together with careful prealigning of the head mount pivots (Figs. 3 and 4) make it possible to replace any head on a drum by any standard head out of stock without adjustment and without loss of information on the tracks involved. According to Stanley Cheney who worked on production design of the heads, "The entire operation of replacing a head can be completed in about three minutes."

HEAD TO MEDIUM SEPARATION

Early experimental equipment in which the head operated directly in contact with the drum had indicated that excessive wear of the heads and the medium would make this arrangement impractical. On the other hand, head-to-drum separations that are small compared with the shortest wavelength to be recorded are important in any magnetic recording system. The one-mil wavelength of the high-density file drum made it necessary to obtain a minimum separation in the order of 200 microinches. For a 15-inch diameter drum, problems of mechanical stabilities and tolerances made it virtually impossible to consider fixed out-of-contact head mounting devices. A system of hydrodynamic lubrication of the magnetic heads, developed at the Laboratory for Electronics, provided the small separation required and made it independent of long term mechanical instabilities such as are produced by aging of castings or fatigue in other metal parts. Controlling the temperature of the lubricating oil made the separation independent also of wide ambient temperature variations.

Head lubricating oil is sprayed continuously onto the surface of the vertically mounted drum. It flows down and off the bottom edge into a sump from which it is pumped through two filters and back to the spray discharge pipe. Interlocking valves prevent the drum from turning without suitable head lubrication. In operation the heads ride on a film of oil at a separation from the drum surface of 180 microinches. The method of mounting the heads using a single pivot allows the head faces to automatically align themselves with gaps of minimum separation (Fig. 5). The head pair is prevented from rotating around the axis of the pivot by the use of a "tail" that extends back from the head and engages a slot in the head mount (Fig. 2). The double track design prevents rolling and the spring loaded head mount prevents pitching.

The drum unit is totally enclosed in a rigid air- and oil-tight aluminum housing and mounted on a cast aluminum base. Direct connections for all recording heads are brought through hermetically sealed terminals in headers in the base casting.

The HD File Drum cabinet contains a final write amplifier and a read-out preamplifier. The output transformer of the write amplifier and the input transformer to the preamplifier are connected simultaneously to a selected head so that no delay is introduced in going from a reading to a writing operation.

The write amplifier consists of two strings of four parallel current stabilized output tubes. Writing waveform is double-pulse-return-to-zero. The preamplifier is a linear feedback pair with a cathode follower output and a closed loop gain of 300. The input transformer provides a step-up of 10 to 1, thus delivering approximately 30 millivolts to the first amplier tube.

SYSTEM APPLICATION

Initial design application called for double-pulse-return-to-zero recording; self-clocked, asynchronous read-out; an eight-bit alphanumeric code; and variable block length. "These requirements depend largely on system specifications," said Murray Hale, in discussing the electronics of the drum application. "The basic drum unit may be used with a variety of code and block structures and alternative writing and reading methods over a wide range of pulse packing densities."

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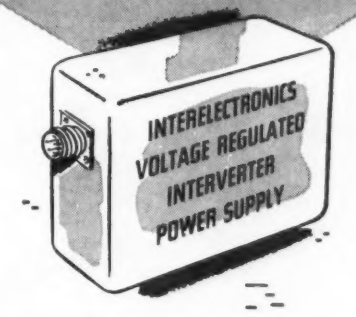

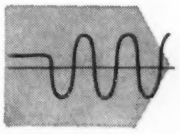

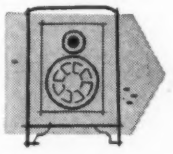

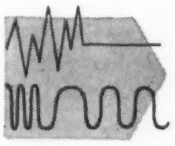

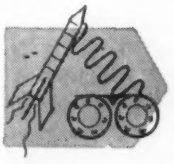

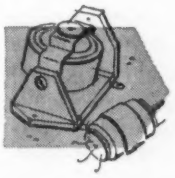

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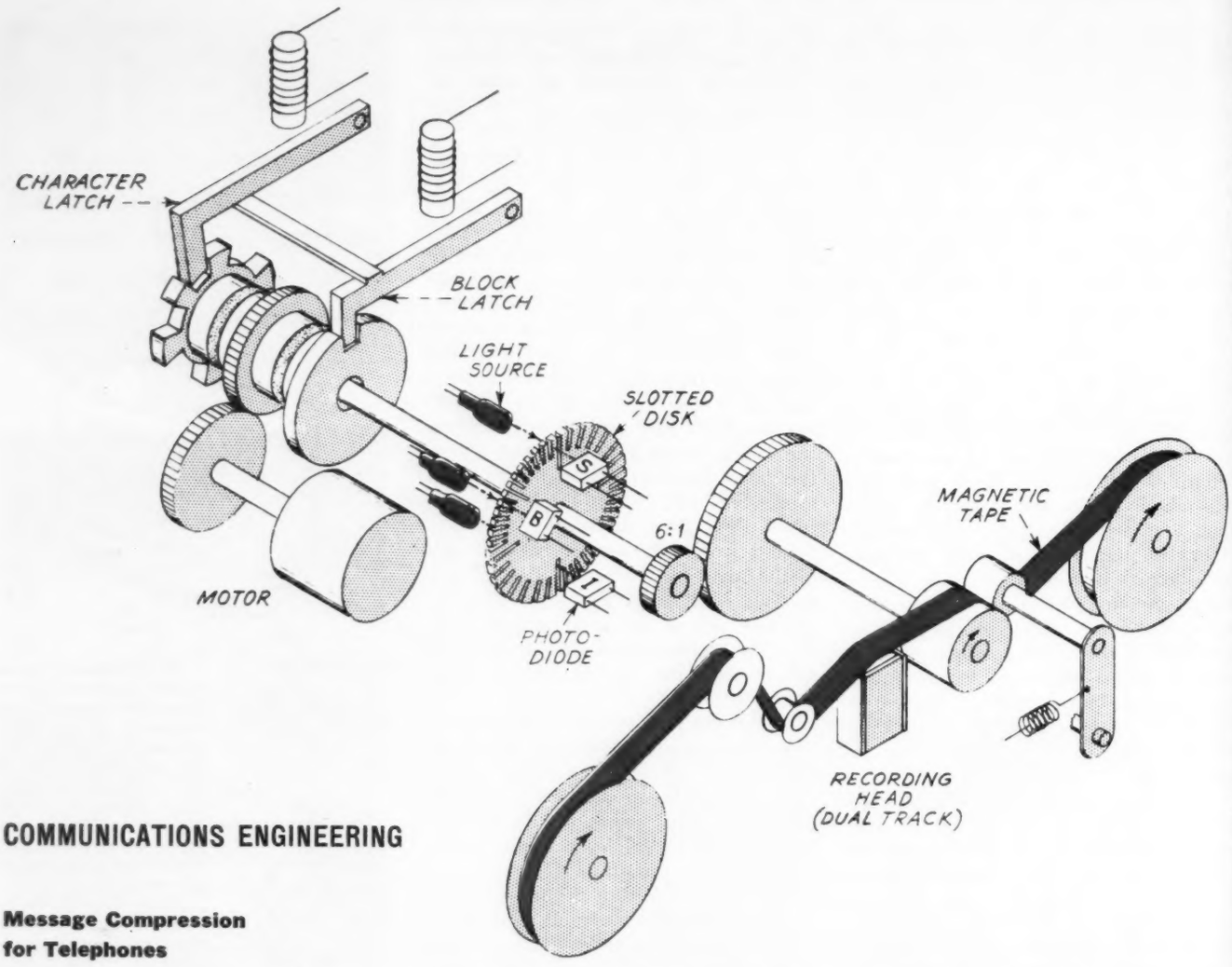

COMMUNICATIONS ENGINEERING

Message Compression for Telephones

Business information ranging from relatively slow typewritten messages to that from fast automatic data processors can now be sent over the ordinary voice-band of a telephone at a rate approximating 750 words per minute.

In an experimental data transmission system, made by Bell Telephone Labs., magnetic tape is used to store information from a typewriter as a means of using telephone transmission lines at signaling speeds determined by the transmission capabilities of the lines.

"Data subsets," with automatic checking and control features to eliminate transmission errors, feed typewritten information into the telephone line at one station and take it out from the line at another. At the receiving end the information is transcribed at normal rates on a regular, electric business typewriter which has been modified to react to the incoming data. The information is sent in blocks of data equal to one typewritten line. However, any normal business machine could be used and any block lengths established (Fig. 3).

The project had as its primary objective the design of a small and relatively inexpensive digital-data set for use with telephone lines. Three of many problems solved in designing the data transmission system were peculiar to the system.

- The varying speeds of business machines plus the efficient rate of transmission of telephone lines had to be considered.
- There was the possibility of error in transmission which had to be caught before it was transcribed at the receiving end.
- Differences between power line frequencies at the transmitter and receiver, differential stretch or slippage of the magnetic tape, noise picked up during transmission of the data, and transmission synchronization jitter could all cause variations in the spacings of the bits on the magnetic tape at the receiving end.

The problem of varying speeds was solved as has been indicated by using magnetic tape to record messages at typewriting speed and then sending and receiving them at an efficient telephone line rate.

FIG. 1—Magnetic tape recording mechanism. Operation of a key on the typewriter, in addition to printing a character on the typed page copy, stores the coded version of the character in a shift register of an associated circuit over seven parallel leads. A mechanical latch tripped immediately thereafter permits the tape to move continuously through the seven places of one character position. An opaque disk geared to the tape capstan rotates between a light source and an array of photo-diodes. Through slots in this disk, an accurate photoelectric indication of the mechanical position of the tape capstan is obtained. Such a photoelectric signal provides an advance pulse to the shift register each time the tape has moved 1/150 of an inch. These pulses spill the bits of the coded character one after another from the shift register to the magnetic tape. This process is repeated on each operation of a typewriter key to produce a single continuous track of positive and negative magnetic spots along the tape, accurately spaced at 150 to the inch. These spots represent the binary "one" and "zero" code bits of successive characters. A second photoelectric signal, occurring once per character of seven bits, places an index spot midway between the seventh bit of one character code and first bit of the second. The block latch, triggered by the action of the typewriter carriage return, activates the third photodiode to separate the message into signal blocks for transmission.

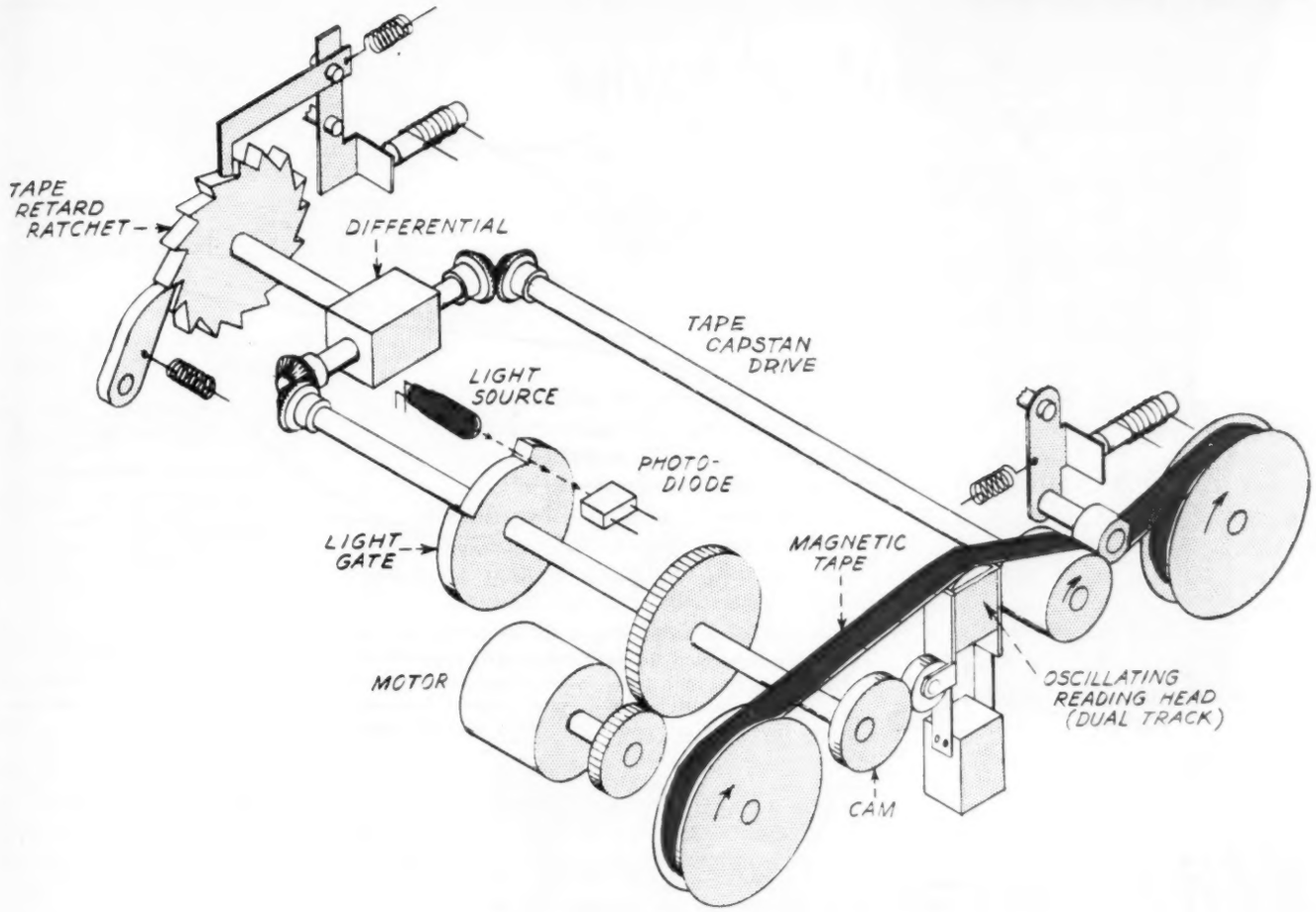

FIG. 2.—Magnetic tape reading mechanism. On the reading end, the tape moves continuously while receiving information, thus it contains all data including blocks with errors. The reading head is oscillated back and forth along the tape by a cam. The tape capstan drive brings a new character under the head at each oscillation. A photoelectric signal, occurring each time the head is moving at constant velocity in the direction opposite to the tape drive, activates the reading circuits. Variations in average bit spacing are compensated in the reading mechanism by servoed positional corrections to the tape capstan drive. The tape is intentionally driven at a speed slightly higher than required by a tape having minimum bit density. Action of the tape-retard-ratchet to the normally stationary third leg of the differential retards this motion at appropriate times to keep the character groups centered on the reading head. These corrections are made during the non-reading part of the head oscillation cycle.

ERROR DETECTION

Detection and correction of transmission errors was accomplished by an ingenious device. The taped message is transmitted over the lines in the reverse order from that in which it is prepared, incidentally eliminating rewinding of the tape. This procedure makes possible acknowledgment of a block of received data before the block is transcribed on the typewriter. The receiving data subset monitors each block of data for errors, as will be described and acknowledges it for transcription or requests a repeat before acknowledgment. Thus, a faulty version of a block which has to be repeated is omitted from the printed copy. The transmitter sends out a block of the message and then stops (Fig. 4). If acknowledgment from the receiver is OK, the transmitter sends out the next block of the message. If the acknowledgment is NG, the transmitter backs up and repeats the last block. This process continues until all the blocks have been received properly. When the last block has been recceived, the data subsets stop finally. (Fig. 4).

In monitoring errors at the receiver, the receiving subset uses clock pulses at the signaling bit rate to sample the incoming data. The clock to provide these pulses maintains the correct frequency by observing changes in the incoming data from "one" to "zero" and vice versa. The clock pulses are used as the input to a "divide-by-seven counter" which provides an "index" pulse every seven bits for use in detecting errors of omission. This counter is started in the correct phase by the recognition of the supervisory code at the beginning of a block of data. The output from this counter is used to record the "index marks" on the received tape. The parity of each character is recorded by a binary counter which is triggered by the simultaneous occurrence of a clock pulse and a "one" in the data. At the end of each character, this binary counter is inspected by an output from the seven counter and is reset. If the binary counter is in the wrong state at the end of a character, then an "error flip-flop" in the control circuitry is set which serves as a memory that a parity error has occurred. In the receiver this flip-flop determines the nature of the subsequent acknowledgment (Fig. 2).

On reaching the end of a block, the transmitter stops its tape and waits for an acknowledgment. At the receiver the tape moves continuously. At the end of a block, the receiver generates and transmits the proper acknowledgment and also records it on the received tape. Hence the received record of the message, which contains all the received data including blocks with faulty characters, has an in-

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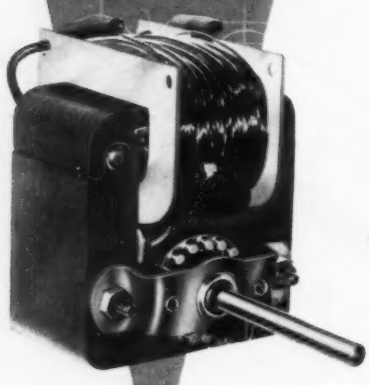

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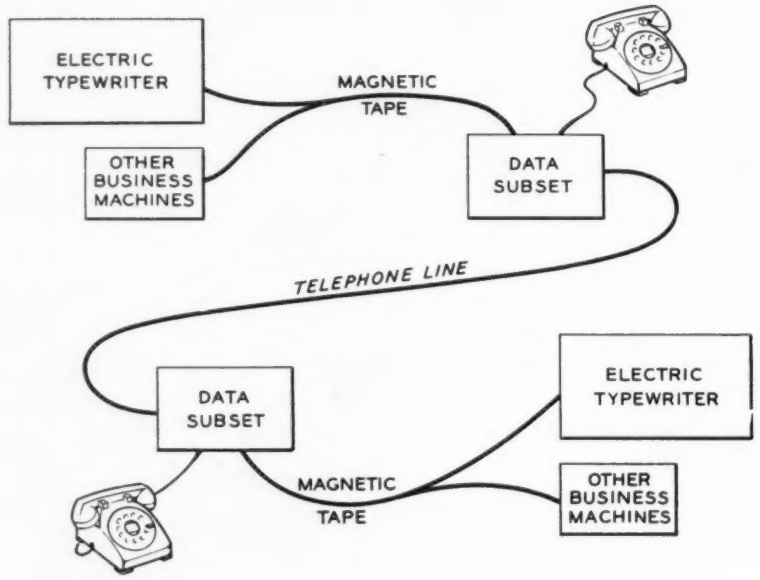


FIG. 3—System schematic. Two magnetic tape mechanisms together with associated circuitry connected to modified electric typewriters produce or reproduce digital coded data on a magnetic tape. A combined transmitting-receiving device, called a data sub. set, with automatic checking and control features sends information through the telephone line from one end and receives it at the other.

dication of which blocks were received with errors and were repeated.

SPACE VARIATIONS

Variations in the spacings of the bits on the magnetic tape at the receiving end are compensated in the reading mechanism by servoed positional corrections to the tape capstan drive. The mechanism and circuitry are arranged so that each character is printed by the typewriter once and only once, and positional variations of the bits within a character do not prevent its recognition.

This design was described by W. A. Malthaner of Bell Telephone Laboratories at the Wescon Session of August 21, 1957.

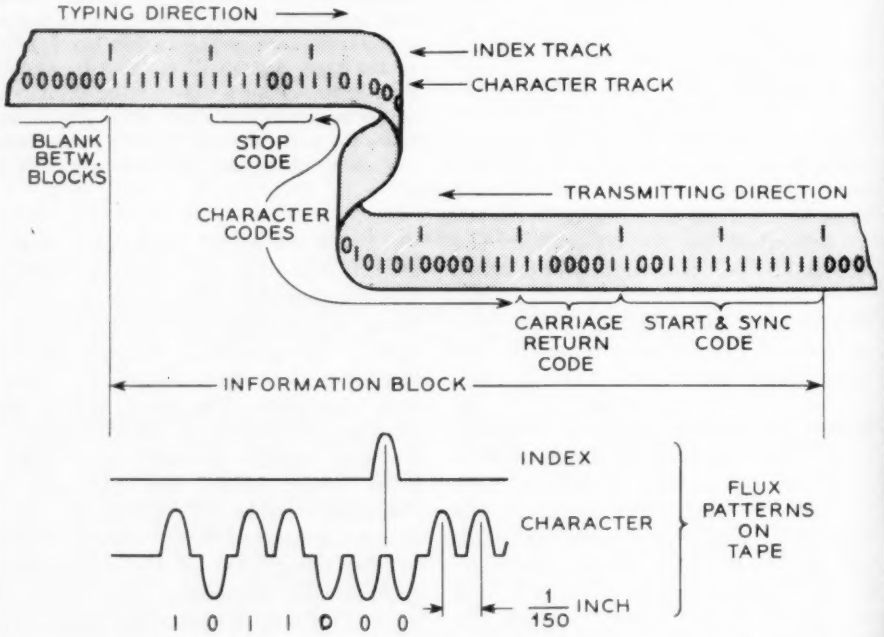
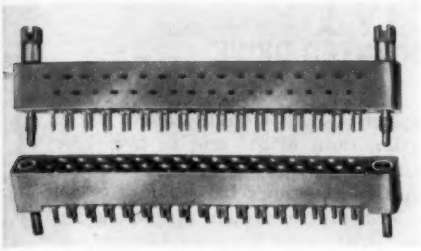


FIG. 4—Section of original recorded tape showing the form in which the data is transmitted. Each character or control group consists of seven bits. A character group consists of three or five ones with the remainder made up of zeros. In this case the information block consists of the amount typed on one line of a typewriter. These information blocks could be of any length but should balance probability of error in a block versus time for repeating block in case of error.

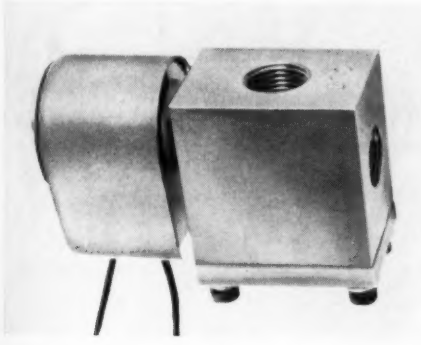
COMPONENTS



Printed Circuit Connector With Polarizing Screwlocks

Printed circuit connector with patented polarizing screwlocks and right-angle construction meets airframe requirements for vibration and high altitude. Contact spacing is based on 0.100 grid in accordance with the latest Electronic Industries Association (formerly RETMA) printed circuit specifications. Designed for printed board or printed cable applications, these Series 683 connectors are available with 11 or 33 contacts. Standard molding compound is Mineral filled Melamine (MIL-P-14E, Type MME). In addition to the regular solder cup for No. 20AWG wire, receptacles can be supplied with taper pin termination for solderless wiring. Electronic Sales Division, Dejur Amsco Corporation, Long Island City 1, N. Y.

Circle No. 196 on Inquiry Card.



High Pressure Solenoid Valve

A two-way solenoid valve, especially suited for hydraulic applications, such as hydraulic lifts and elevators, is designed for tight shut-off on pressures to 1500 psi. They may be mounted in any position without affecting operation. Valves are of the internal pilot operated piston type having angle bodies, available in either stainless steel or brass bar stock with teflon discs and stainless steel magnetic parts. They may be supplied for continuous or intermittent service, depending upon the application. Automatic Switch Co., Florham Park, New Jersey.

Circle No. 184 on Inquiry Card

Difficult batching problems solved by Autoweightion*

- *All types and combinations of materials successfully handled*
- *High degree of accuracy obtainable*
- *Thayer Scale Flexure Plate Leverage System guaranteed accurate for life*

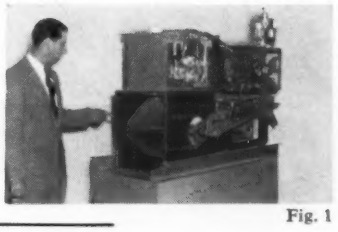


Fig. 1

The development of the Thayer Autoweightion System for controlling materials processing systems has opened the door for many hitherto impractical batching operations. For instance, several different flushing materials (flooding powders) can now be handled without leakage by a tipping bucket weigh hopper (Fig. 1) controlled by a series of different range Thayer weigh beams.

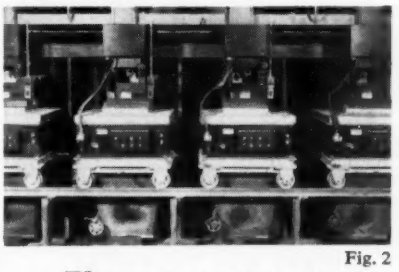


Fig. 2

Thayer individual batching scales can be used to furnish preweighed charges which may be varied in weight to suit the formula. The system shown (Fig. 2) can be furnished to allow positioning under various bins or feeders so each scale will preweigh a given weight charge and discharge it to a conveyor belt or to a mixer for further processing.

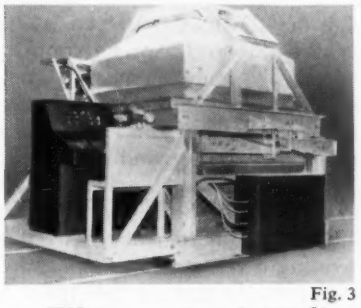


Fig. 3

Where many ingredients are to be handled and there is a factor of space saving and a minimum amount of equipment, it is possible to utilize an accumulative batching scale which can either be fixed or moveable as shown (Fig. 3). This unit will have a large weigh hopper sufficient to accommodate the total weight of any number of ingredients desired to be accumulated. To secure accuracy in various weight ranges, the weighing of each individual ingredient will be controlled by its own weigh beam on the scale and the various ingredients will be weighed into the common weigh hopper in turn at the prescribed formulated weight.

Difficult to handle materials, such as hot tar, high viscosity liquids and other such ingredients which leave a residue in the weighing vessel can be handled in a loss-in-weight manner by first precharging a vessel to any weight and then withdrawing a known amount for the desired charge (Fig. 4). By this means the remaining tare weight within the hopper will not affect the weight of the next discharged load. Such a unit can be used either as a single batching scale or as an accumulative batching scale discharging in a loss-in-weight manner.

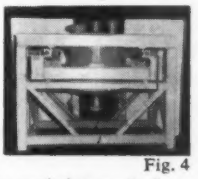


Fig. 4

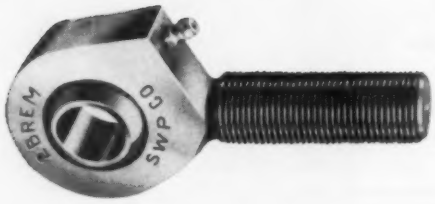
Engineered solutions such as these have put Thayer batching systems into many of the best known processing plants in North America. Thayer builds a complete line of feeders interlocked with Thayer Scales. Remote controls, adding machines and chart indicators are also supplied. Please write us about your batching problems.

AUTOWEIGHTION
trade-mark
* THE THAYER SYSTEM OF PROCESS CONTROL BY WEIGHT

THAYER SCALE CORP.
16 Thayer Park, Pembroke, Massachusetts

FOR MORE INFORMATION CIRCLE 51 ON INQUIRY CARD

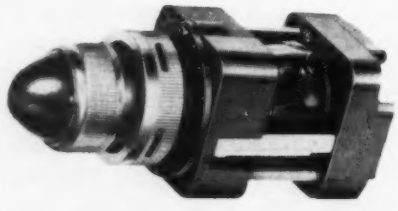
COMPONENTS



Rod End Bearings

A new line of two-piece (ball and body only) self-aligning, plain, spherical, rod end bearings for the aircraft, missile and related industries is patterned closely after the firm's Monoball self-aligning rod end bearings. The new two-piece rod end bearings are claimed to have longer cycle life compared to three-piece rod end bearings because of the construction and tougher materials used. The bearings are said to reduce lost motion in linkages and withstand excessive vibration. They carry heavier loads than anti-friction types since they have a greater surface supporting area. The bearings are available in sizes for ¼ to ¾ inch bore and larger, with capacities of radical ultimate loads from 7000 to 33,300 pounds and higher. Same bore sizes available for high-temperature operations to 1000 degrees F. Southwest Products Company, Monrovia, California.

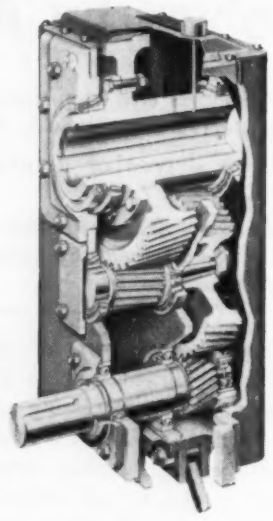
Circle No. 182 on Inquiry Card.



Push-To-Test Pilot Light

Push-to-test pilot light has a separate circuit for testing the bulb simply by pushing on the color cap. In the test position a positive contact "feel" eliminates any doubt of whether the unit is in the test position. Oil-tightness is maintained in both the normal and the depressed or test position. There are no wires to be broken since all internal connections are pressure connections of silver-plated beryllium copper. Square D Company, Milwaukee, Wisconsin.

Circle No. 175 on Inquiry Card.



SHAFT MOUNTED DRIVE

A large capacity, shaft mounted drive in a single reduction ratio of 5:1 and in two double reduction ratios of 14:1 or 25:1 is now available. Unit ratings range from 2hp at 5rpm to 50hp at 359rpm; maximum torque rating at low speed shaft is 31,000 pound-inches. A longer center distance between shafts permits use of larger sheaves on installations where unit is mounted with input shaft toward driven machine or on through-shaft applications. Inspection covers on the 3-wall, one-piece, all steel housing provide easy inspection of bearings and helical gears. An automotive type dip stick permits a quick check of oil level. The Falk Corp., Milwaukee, Wisconsin.

Circle No. 189 on Inquiry Card.

Precision Interval Timers

A new series of precision interval timers, hermetically sealed and designed on the basis of a repeat cycle timer, has a novel switching system that allows high accuracy over long range timing intervals. Available with either chronometrically governed d-c motors or synchronous a-c motors these units possess 1% accuracy or better. Application requirements control the range of adjustment; overall ranges in excess of 30 to 1 can be supplied. A hermetically sealed adjusting knob on the front of the unit allows rapid and accurate setting of the calibrated dials within the glass window. A double dial provides maximum setting ease and accuracy with one dial showing the major setting increments and the other providing a vernier adjustment of these increments. Design of this timer eliminates the need for any form of clutching system and therefore no standby power is required when the unit is time out. Power consumption is limited to a few watts since the only electrical requirement is for the motor. A. W. Haydon Company, Waterbury, Connecticut.

Circle No. 200 on Inquiry Card.

Rotary Valve

Teflon shear seal principle prevents leakage at all pressures in a rotary valve designed for fluids or gases under operating pressure of 3000 psi. Proof pressure is 4500 psi; burst pressure is 7500 psi. The valve is full ported straight through for minimum pressure drop. Handle torque at operating pressure is less than 45 inch-pounds and rotates 90 degrees for full on or full off. Detent stops are provided in both positions; flow is bi-directional. Temperature range: −65 F to +275 F. It is designed for hydraulic test stands, and engine air starters. Vinson Manufacturing Co., Van Nuys, California.

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SILICON JUNCTION DIODES

These latest additions to Clevite's complete line of computer and general-purpose diodes offer you the advantages of:

ULTRA FAST RECOVERY TIME . . . (JAN-256)
(Typical: from +5.0 ma to −40v
. . . 400K in 0.3μs)

HIGH FORWARD CONDUCTANCE
(Typical: 50 ma at 1.5v)

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FOR MORE INFORMATION CIRCLE 52 ON INQUIRY CARD

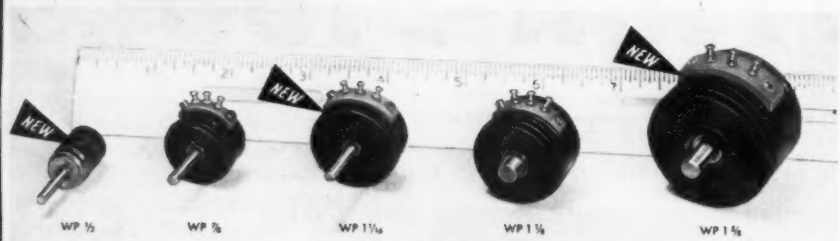
BIG-POT PERFORMANCE in Miniature-pot size

Waters PRECISION MINIATURE POTENTIOMETERS

are built, tested, and certified* to such rigid specifications as AIA, RETMA, JAN-R-19, MIL-E-5272A, and other applicable military specifications. *This new line* of single-turn pots packs Waters traditional performance into tight spots.

NOW! A complete single-turn-pot line from Waters

*Complete data on request.



BIG-POT PERFORMANCE in Miniature-pot size

Waters ROTARY TRIMMER POTENTIOMETERS

are built, tested, and certified* to rigid military environmental specifications and are available in many variations: ganged, tapped, with various electrical and mechanical angles, locking shafts, anti-rotation pins, "O" rings, etc.

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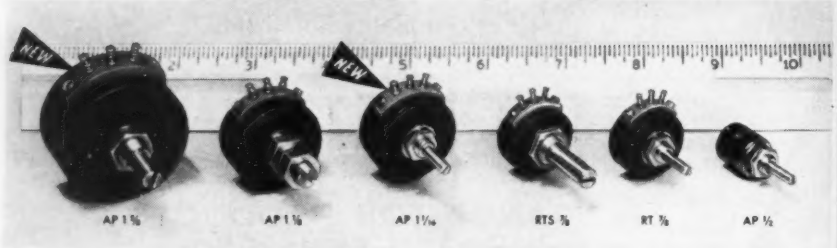

Write for catalog of the Waters complete single-turn pot line — precision, trimmer, low-torque, miniature.

Waters MANUFACTURING, inc.

APPLICATION ENGINEERING OFFICES IN PRINCIPAL CITIES

Wayland, Massachusetts

FOR MORE INFORMATION CIRCLE 53 ON INQUIRY CARD

DETECTION

Photoelectric Device Uses Radioactive Light Source

A miniature, low-cost photoelectric system constructed entirely of solid state components uses a radioisotope radiation source to replace the unreliable incandescent light source of conventional systems.

The new system, consisting of a radioisotope source, cadmium sulphide radiation detector and transistor amplifier (Fig. 1), combines much of the versatility of photoelectric control with the reliability of solid state components. The device has its greatest advantage in applications where reliability is most critical and equipment is inaccessible for maintenance.

The shortcomings of an ordinary light beam in dusty or smoky environments suggested the use of a beam of more penetrating radiation. Such a beam can be both generated and detected by small, rugged solid state components. A small amount of suitably chosen radioactive material furnishes an easily detectable beam of high-energy radiation unaffected by temperature, shock or nearly any other environmental condition. The radioactivity decreases with time at a rate depending only on the half-life of the isotope, so that diminution of source

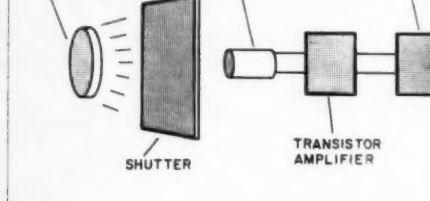

FIG. 1—Physical arrangement of components. A model of the new solid state photoelectric system was built and tested, using a 1 millicurie strontium-90 source and a Hupp-13 CdS detector. The source used is about ⅛ inch by ½ inch diameter with shielding. The photocell is ½ inch by ¼ inch diameter, the active sensing area being less than 1/16 square inch in size. The radiation reaching the detector is controlled in the test system by a 1/32 inch aluminum shutter interposed between source and detector. Removal of the shutter irradiates the photocell, decreasing its resistance, changing the output from off to on. Even with the large source used (½ inch diameter) the resolution of the critical position of the shutter is about .005 inch.

strength at any time can be compensated exactly.

These attractive features of radioisotope sources are being used commercially in several industrial control devices. Best known among these is the beta-ray thickness gauge, which measures and controls high speed, continuous sheet materials to within one percent thickness. The isotope used in most of these gauges is strontium-90, which retains half its activity after 25 years, a convenient decay rate for most commercial devices.

The radioactive material as produced by the AEC operated pile is in the form of an aqueous solution containing the isotope. Chemical processing is then used to concentrate the active material into a solid, compact form. The radioactive solid can then be permanently sealed in a stainless steel container, with one face thin enough to pass most of the emitted radiation. Radioactive sources thus processed and packaged are obtainable from several firms specializing in radioisotopes.

The mechanism of detection is the decrease in resistance of the photocell in the presence of radiation. The cell is incorporated in a bistable transistor circuit whose output state depends on the cell resistance. When the cell resistance falls below a certain level, the output changes sharply from off to on in a fraction of a millisecond, setting off an alarm or actuating some control element.

The information on this system was taken from a conference paper by Paul Weisman and Stanley L. Ruby of Westinghouse Electric Corporation read at the AIEE Fall General Meeting in Chicago October 7-11, 1957.

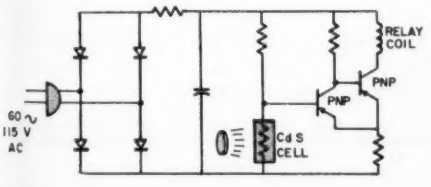

FIG. 2—Bistable transistor circuit incorporating photocell. The CdS cell is characterized by a rather slow change of resistance after sudden application or removal of radiation. The transistor circuitry can be adjusted to switch states at a photocell resistance only slightly below the "dark" value, giving a fast off-to-on response but a slow on-to-off response; or vice versa. However, the expected change in circuitry characteristics with temperature, or possibly with age, makes it inadvisable to balance too close to either extreme of the photocell resistance range. A reasonable compromise gives response times of about 0.2 second and an over-all counting rate of about one piece per second.

NEW Development!

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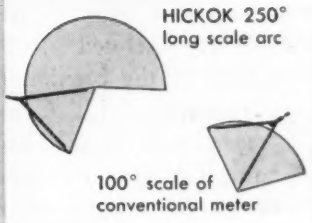
The scale in these new instruments is 2½ times as long as conventional meters. A 3½" HICKOK 250° meter has a scale length equal to a conventional 6" instrument.

These exclusive panel style 250° meters fit a smaller space though still provide easier, more accurate readings.



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UNIFORM SCALE

Evenly Spaced Scale Divisions

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AC rectifier or DC types

The highly efficient HICKOK shock mount construction permits pointer and scale divisons to be easily read when meter is under vibration. The DC movement is a precise and rugged internal pivot type. The AC movement is of the iron vane principle with unusually efficient magnetic damping for ruggedized purposes. Case is permanently sealed at the factory, however, may be opened and resealed.

These instruments meet military specifications and are in volume production. Your inquiry is invited. Kindly list details of your requirements or request Catalog No. 33.

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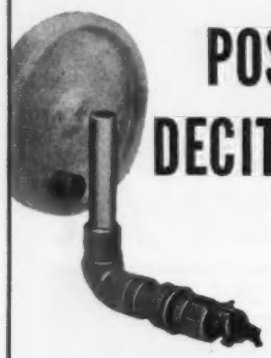
MODEL MH-2



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Magnetic Switch

Post's DECITRON Magnetic Switch is an ideal sensing device for actuating counters, controls, solenoids, relays and many other electrical or electronic circuits.

The Post MH-2 is magnetically operated . . . controlled by the proximity of a magnetic field. A *clean "make" and "break"* is accomplished *at any speed range* from zero to 100 cycles per second.

"Bounce" is eliminated by using a capillary film of mercury. For timing . . . synchronizing . . . or counting . . . specify the dependable, long life — MH-2. Write for literature.

Decitron Electronics Products Division

POST

POST MACHINERY COMPANY

Beverly, Mass.

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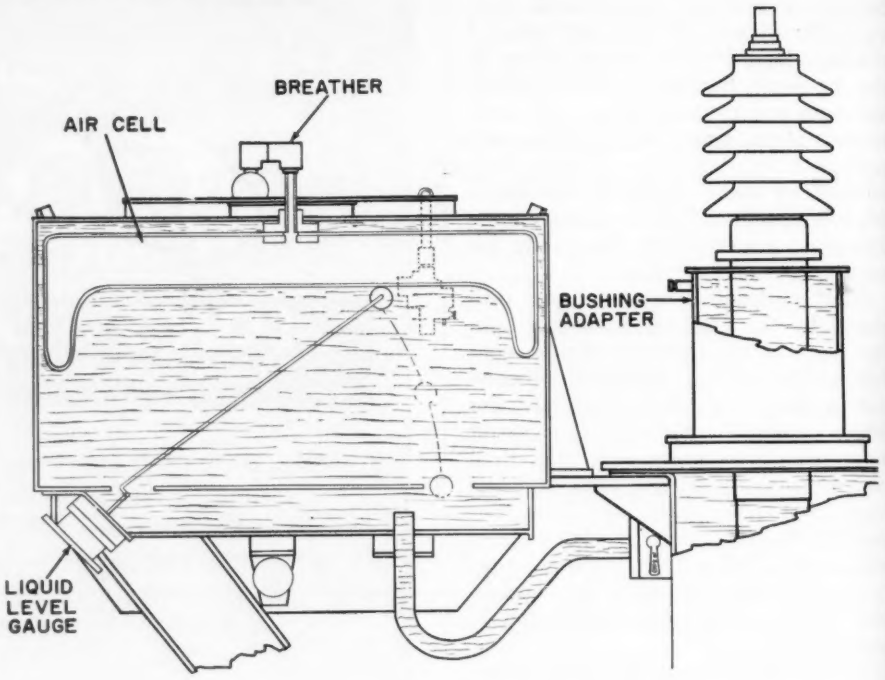


Cutaway of oil preservation system for G. E.'s power transformers shows how rubber air cell expands and contracts as oil volume in transformer tank varies with temperature.

COOL TRANSFORMER

Rubber Air Cell Controls Oil Pressure

A new constant-pressure oil preservation system for power transformers (units above 10,000 KVA) eliminates both oil-to-gas contact and wide pressure variations, helping to prevent hazardous bubbles from developing in the transformer oil. Main design in the "Atmoseal" method is a rubber air cell in a rectangular expansion reservoir located beside the transformer cover. As oil expands inside the transformer and flows into the reservoir, the nylon-impregnated Nitrile rubber cell deflates and exhausts air to the atmosphere through a weather-tight breaker. When the oil cools and contracts with reduced load or ambient, it flows back into the main tank and atmospheric pressure reinflates the rubber cell. At no time does air come in contact with the oil.

Major advantage of the new system is the prevention of gas bubbles in the oil, according to G-E engineers. Most other oil preservation methods permit large pressure drops which can release dissolved gases in the form of bubbles from the oil, reducing its dielectric strength. With the Atmoseal system, oil pressure can vary only about 0.6 psi throughout the transformer's operating cycle from an almost empty reservoir to a full one—with a temperature change of 120 C.

Additional benefits include negligible maintenance: there are no gas cylinders to replace or controls to adjust; reduced fire hazard; bushing adapters keep head of oil below the level of external bushing porcelains so transformer oil cannot bleed from a damaged bushing; and reduced line interference. Low reservoir height provides greater distance between lines and ground. Additional details are available in a new bulletin, GEA-6626, available from the General Electric Company, Schenectady, N. Y.

For your copy circle No. 201 on Inquiry Card.

WORTH FILING

Calibration Chart for Thermocouples

Durable chart contains color codes and calibration symbols for thermocouples and thermocouple extension wires plus pyrometer wire resistance figures. Resistances are given for standard pyrometer wires in ohms per 100 feet at 68 degrees F. They include resistances for solid conductors (individual and loop) from 1 to 40 gage and for stranded conductors (individual and loop) from 14 to 28 gage.

Source: Thermo Electric Co., Inc., Saddle Brook, N. J.

For your copy: Circle No. 208 on Inquiry Card

MACHINE TOOL CONTROL

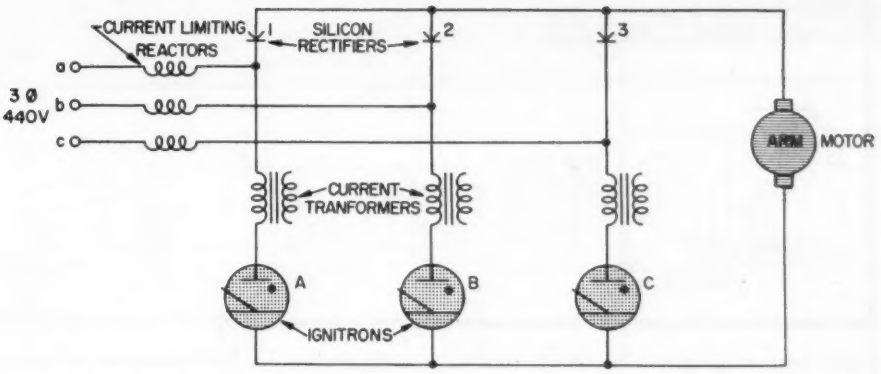
Regulated Electronic Speed Drive

Electronic speed drives are rapidly taking the place of motor-generator sets. They are said to have faster responses, easier control, and more efficiency. They are also said to be smaller, lighter and quieter.

Taking advantage of recent developments in solid state devices, Raytheon Manufacturing Company of Waltham, Mass., has developed a regulated electronic d-c speed drive, rated from 30-100 horsepower, for machine tool and similar applications requiring close speed regulation, fast response, and wide speed range.

"The design philosophy for the system," according to Mr. Winston S. Harvey who developed it, "was to eliminate all vacuum tube amplifiers and to simplify the power rectification system in order to make the assembly as small as possible and to minimize failures."

Fast-response magnetic amplifiers, germanium transistors and gold-bonded diodes give the desired system gain. The power rectifier system provides 3-phase full-wave operation at rated armature voltage with only 3 ignitrons and 3 silicon rectifier arms. Other systems use 6 ignitrons or equivalent mercury-pool rectifiers with the necessary added firing and control circuits. The silicon rectifiers are forced-air cooled; the ignitrons are water-cooled. To conserve water and prevent moisture condensation, thermostats control the water in the ignitron so that it only flows when temperature exceeds a pre-set value.

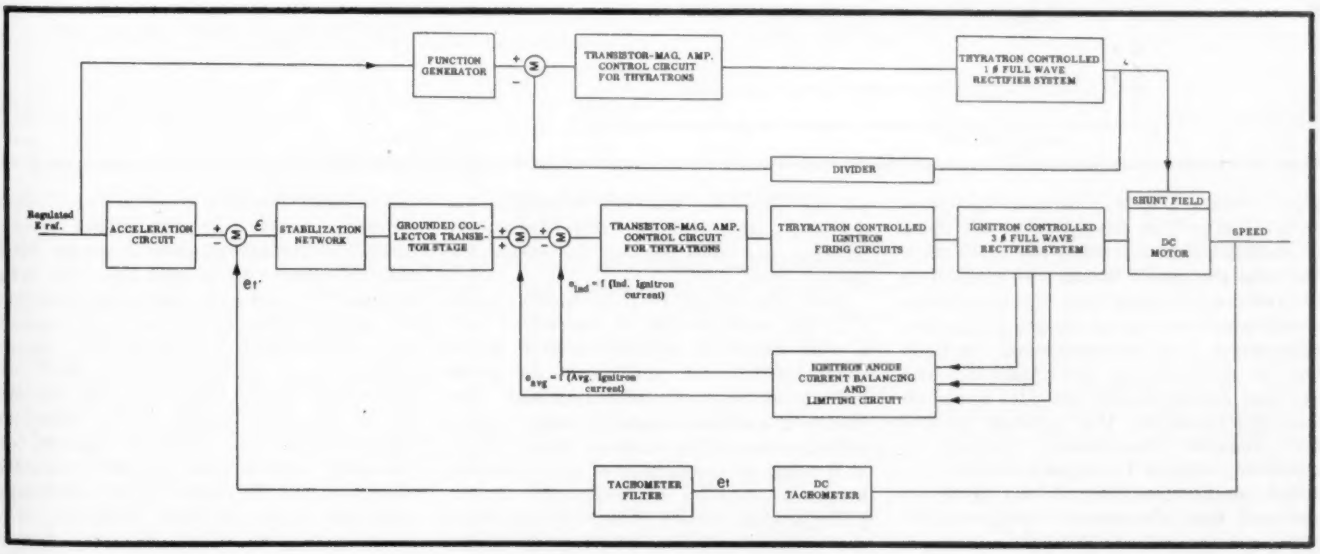


Simplified armature voltage supply system. Three-phase line voltage is applied directly to input of rectifier system through surge current limiting reactors. Since there is always one of the silicon rectifiers in series with each of the ignitrons, only three ignitrons and associated firing circuits are required to obtain 3-phase full-wave rectification at rated speed and load. For example, with phase (a) most positive and phase (c) most negative, current will flow from phase (a) line through ignitron (A), the motor armature, and rectifier 3 to the line of phase (c) when the (A) ignitron is triggered. The firing angle of the ignitrons, which determine the armature voltage, is controlled by varying the firing angle of the associated thyratrons.

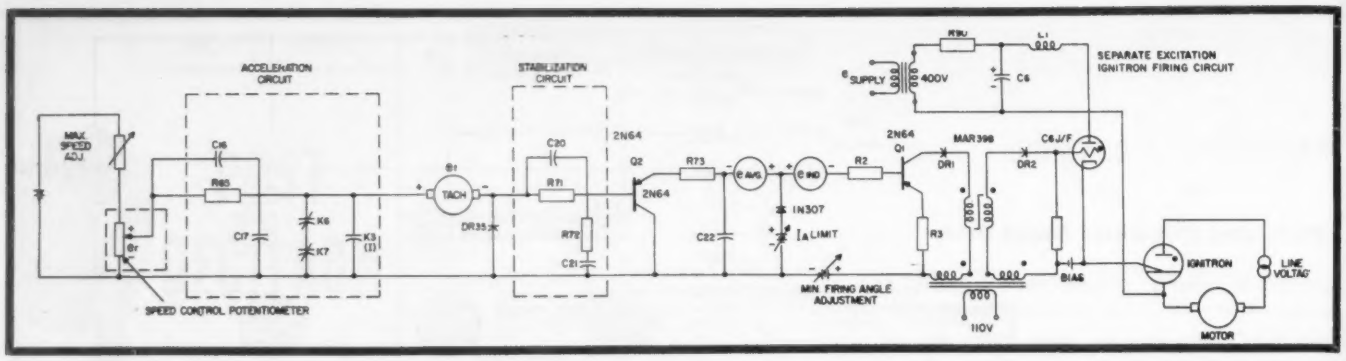
OPERATING CHARACTERISTICS

The system consists of a control unit and d-c motor. A motor that develops constant horsepower over a portion of its speed range is required for constant horsepower load applications. It must be capable of operating over constant torque or constant horsepower ranges at full load without over-heating. The system has the following operating characteristics:

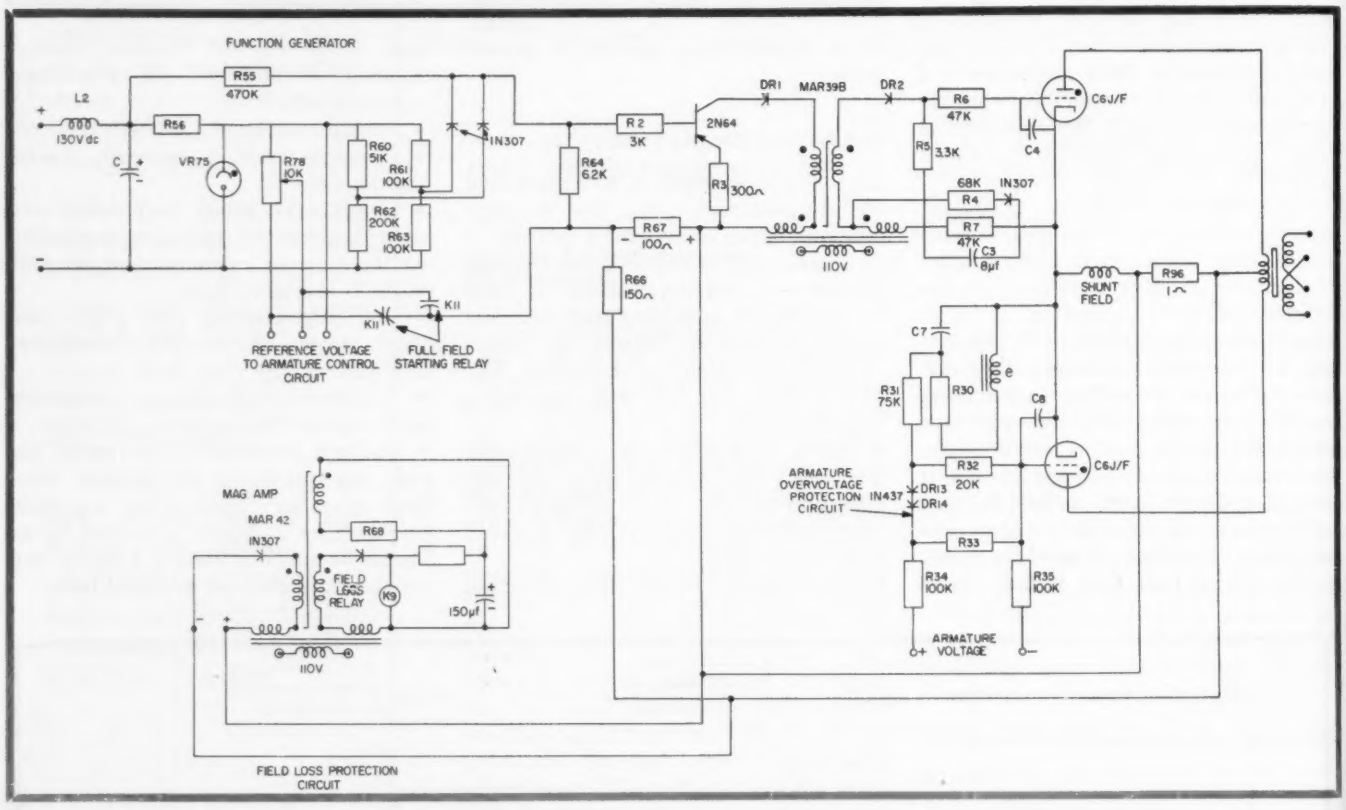
- Speed regulation by tachometer feedback. The system gain and stabilization may be easily varied to provide optimum regulation for a given motor and load
- Acceleration control in conjunction with surge current limiting reactors eliminating the need for a reduced voltage starter
- Armature current limiting
- Dynamic braking, forward, reverse and jogging
- Combined constant torque and constant horsepower operation dependent on the type of motor and application
- Field loss protection
- Full field starting with either constant torque or constant horsepower applications
- Armature over-voltage protection with constant horsepower operation
- Fail-safe protection. The control circuits are protected by thermal overload relays and fuses while the armature rectifier system is protected by an instantaneous trip circuit breaker and an armature thermal overload relay.



Block diagram of regulated electronic speed drive system.



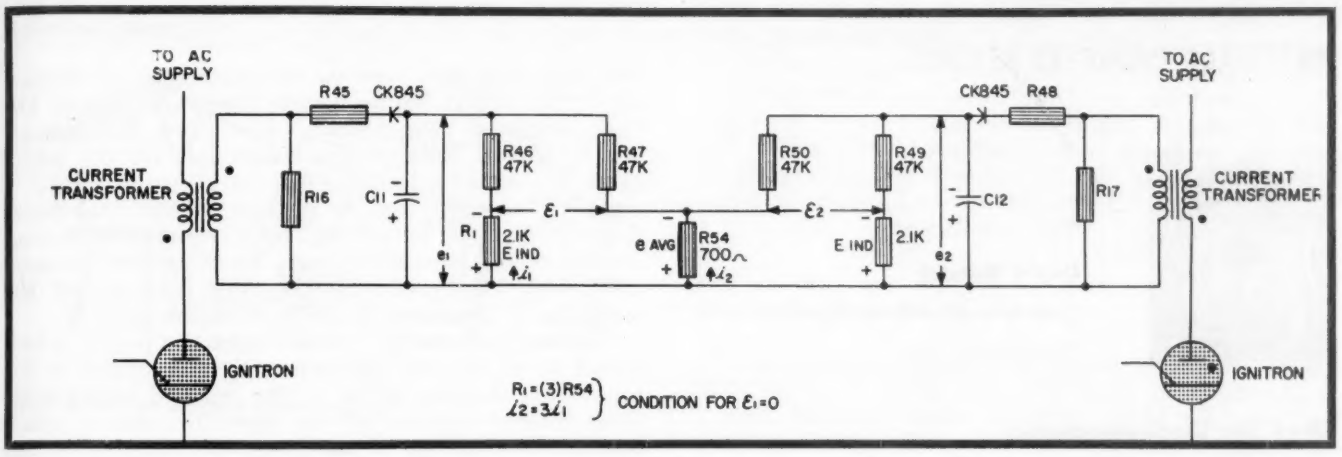
Equivalent single-phase armature control system. The thyratrons are part of a standard energy-storage firing system, separately excited. Transistor controlled magnetic amplifiers vary the firing angle of the thyratrons. This type of firing circuit providing isolation between the control and power stages and pulse firing for the thyratrons is ideally suited for thyratron control. The grounded-emitter transistor controls the amount of reset during the control half cycle and thereby the firing angle during the load half-cycle operation of the magnetic amplifiers. The operating point of the transistor-magnetic amplifier system is a function of the error voltage —difference between reference voltage and tachometer feedback voltage. Varying the regulated reference voltage (e_r) controls the motor speed. By limiting rate of rise of the reference voltage, the acceleration circuit limits motor acceleration for several cycles until the armature current limiting circuit can become effective. Output of the summing circuit is the difference between reference voltage and filtered tachometer output. The stablization circuit improves the frequency response and permits good speed regulation without hunting. The grounded collector transistor stage is necessary to provide a high impedance load for the stabilization circuit and at the same time present a low impedance source for the following three grounded emitter transistor stages which control the firing circuits.



Field control system. Constant horsepower is developed as the speed of the drive is increased by reducing the field flux. To keep the speed linear with respect to the reference voltage over the entire constant-horsepower speed range, a function generator is used to compensate for field-flux vs field-current non-linearities. The function generator also provides a smooth transition between the constant torque and constant horsepower ranges. A grounded emitter transistor-magnetic amplifier combination controls the firing angles and thus the output voltage of the full-wave thyratron field-supply system. A negative feedback circuit keeps the field current linear with respect to the output of the function generator regardless of nominal line voltage or temperature changes and also reduces the system response time.

Since the shunt field is highly inductive, the field current is controlled over a wide range by applying a high amplitude sine wave in phase with the anode voltage of one of the thyratrons. The thyratron conducts when its anode supply voltage exceeds the induced field voltage as a result of conduction of the transistor-magnetic amplifier controlled thyratron.

To prevent armature over-voltage, when the motor is running at rated speed and the reference voltage suddenly reduces, the armature voltage is divided and compared with the output of a Zener diode reference voltage circuit. If the divided armature voltage exceeds a preset level, the reference voltage and thus the firing angle of the normally full firing thyratron is reduced. The field current is reduced to a value which will limit the armature voltage to a safe value. The field loss protection circuit serves to stop the motor if the field current is less than the desired minimum value. To operate dependably over a wide current range, the field loss relay is controlled by a magnetic amplifier with positive feedback. The field current at which the relay deenergizes may be varied by adjusting the feedback.



Simplified automatic anode-current balancing circuit. The balancing circuit, which compensates for the tolerances of the firing circuits, causes nearly equal anode currents to flow through each of the three ignitrons.

A d-c voltage proportional to actual anode current in each ignitron is compared with a d-c voltage proportional to the average current of all three ignitrons. If the voltages giving the measure of the individual currents differ from the voltage indicating average current, an error signal is applied to the appropriate grounded emitter transistor stage to provide balancing action. The armature current-limiting circuit (Fig. 3), which is closely associated with the balancing circuit, compares the individual voltages with a fixed voltage. If the individual voltages exceed the fixed voltage, a diode conducts changing the operating point of the grounded emitter transistors to retard the firing angle of ignitrons and thereby limit the armature current to a value determined by the choice of fixed bias voltage. Each grounded emitter transistor stage in conjunction with a fast-response magnetic amplifier constitutes a high-gain d-c amplifier system whose output pulse fires the respective thyratrons. The thyratrons, in turn, act as switches to discharge the energy stored in the condensers into the ignitors of the ignitrons and thus fire the ignitrons at the proper instant. The L, C and R constants of the firing circuit provide an ignitor pulse of the correct duration. The resulting firing angles of the ignitrons determine the armature voltage of the motor.

- Regulated reference voltage to compensate for ±10 percent line voltage changes
- Balanced ignitron anode currents and thus balanced line currents

DESIGN FOR MAINTENANCE

The thyratron control circuit panels are of a modular design so that a spare control circuit panel may be used interchangeably with any of the speed drives. Ignitor pulse-forming panels are also interchangeable. The only control circuit adjustments necessary in changing motors are easily made on one control panel. All potentiometer adjustments such as minimum firing angle control, current limiting, maximum speed control, system gain and the current balance control are grouped together on this same panel. The control relays and switch gear assembly are located on a separate panel so that control sequence may be easily checked. In general, all of the servicing is done from the front of the cabinet. The rear section contains only the power control transformers, armature rectifier system and power resistors.

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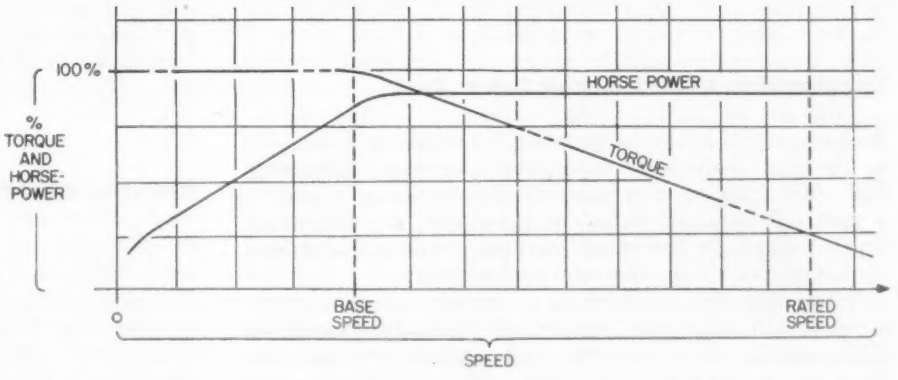

Drive characteristics of electronic speed drive.

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MATERIALS PROGRESS REPORT

STAFF COLUMNIST

David Bandel

Associate Technical Director,

TRACERLAB, INC.

Ideas for Electromechanics

Chemistry, like mathematics, cuts across many scientific and technological borders. Fundamentally, all materials are "chemicals" and their properties reflect their chemical and atomic or molecular structure. For example, in the field of transistors, chemical purity and controlled impurities in the parts per billion range make the difference between a useless, electronically inert lump of germanium or silicon and a highly useful electronic component.

Chemical research has continually furnished the designer with unique new materials that open new approaches for advanced designs and add degrees of freedom in attaining increasingly higher performance. It is not at all surprising then that a meeting of chemists, the 132nd National Meeting of the American Chemical Society in New York, would report new investigations of interest in the field of electromechanical research and development.

Thorium Seen Cutting Atomic Power Cost

Present plans for atomic power call for enriched uranium as the fuel source, a comparatively expensive source of fuel. Speaking at a session of the American Chemical Society's Division of Industrial Chemistry, Dr. Dennis D. Foley of Battelle Memorial Institute reported on studies for using cheaper thorium as a fuel source.

"The successful application of atomic energy requires a continued economic supply of fissionable materials. Uranium-235, plutonium-239 and uranium-233 are the three known fissionable materials. Of these, uranium-235 is the only naturally occurring material and is, therefore, the indispensable element in atomic energy development.

"Plutonium-239, the second fissionable material, can be obtained by the neutron irradiation of natural uranium. Atomic-power activities in the United States today are directly or indirectly based on uranium. However, several power reactor concepts are under development in which, starting with only a small quantity of uranium-235, the third fissionable material, uranium-233, would be produced by the neutron irradiation of thorium.

"In this way, the continued operation of an atomic power plant could be based upon thorium, much more readily obtained than uranium-235 and, consequently, relatively cheap in comparison to it. Thorium is, in fact, three times more abundant than uranium in the earth's crust."

But the procurement of thorium of sufficiently high purity for reactor applications has been one of the most serious problems in atomic energy programs. As part of an Atomic Energy Commission program for the production of pure thorium metal for reactor experiments, laboratory and pilot-plant work on the purification of thorium nitrate was undertaken by Battelle Memorial Institute, Dr. Foley explained. The primary objective of the program was to provide basic process design data for the AEC's Feed Materials Production Center at Fernald, Ohio. A secondary objective was to produce enough high-purity thorium nitrate by solvent extraction to permit making an analysis of the impurities present by actual slow neutron irradiation. This would give a direct measure of the suitability of the material for reactor experiments.

The studies resulted in a solvent extraction process which is said to be the only practical method developed so far for making thorium nitrate of the required high purity. Other existing methods rely on chemical reactions rather than on the extraction of impurities with solvents.

With the new process, a recovery of 99.89 percent of the thorium as a purified product was achieved. In addition, the purity of the product was said to be ample for all anticipated uses in reactor experiments. Copper, an impurity originally present to the extent of 30 parts in a million parts of thorium, was reduced to less than two parts in ten million. And the rare-earth elements—which constitute one of the most serious reactor "poison" problems—were reduced from concentrations as high as 45 parts in a million parts of thorium to as little as 2 parts in a billion, Dr. Foley reported.

"During a six-month period of operation, the process for refining thorium nitrate was successfully developed and demonstrated," he said. "On the basis of the work, it was established that the necessary product purity could be readily obtained and that an extremely high thorium recovery could be expected. Thorium may ultimately play an important role in the world's nuclear fuel supply."

Robert B. Filbert, Jr., chief of the Battelle Chemical Engineering Research Division, was co-author of the paper.

Radiation Chemistry of Polymers Reviewed

In a symposium on Radiation Chemistry of Polymers, A. A. Miller and E. J. Lawton, General Electric Research Laboratory, reviewed the effects of ionizing radiation on polyethylene. They found that in the absence of oxygen, cross-linking was the predominant reaction. This was essentially a free radical process. In the presence of oxygen, the over-all cross-linking efficiency can be reduced to the point where oxidative degradation, rather than cross-linking, predominates.

R. Y. Mixer, Stanford Research Institute, reported on the chemical damage resulting from irradiation of epoxy adhesives. A small amount of chemical change can result in large changes in the physical properties of the cured adhesives. The extent of the damage varies with the epoxy base and hardening agent. Preliminary attempts to improve the radiation resistance with protective agents were partially successful. Epon VIII containing 9.1 percent of 2.5 diphenyloxazone lost only 11 percent of its strength after receiving a dose of 800 megarep, compared with 40 percent lost for the control specimen.

Methods of increasing the adhesion of polyethylene to metals drew some attention. F. J. Bockoff, E. Timothy McDonel and John E. Rutger, Jr., Fenn College and Case Institute of Technology, described the effect of oxidation of polyethylene surfaces on adhesion to stainless steel. Untreated polyethylene showed adhesion of several hun-

dred pounds per square inch. Controlled oxidation produced adhesive strengths in excess of 2500 pounds per square inch, with predominantly cohesive rather than adhesive failure.

New Silicone Rubbers Described

Extensive experimental work on the compounding of silicone rubbers was summarized by F. L. Kilbourne, A. S. Kidwell, R. D. Alling and Z. J. Grabicki, Connecticut Hard Rubber Company. Five years' experimental work led to the development of high-tensile, high-tear-strength silicone rubber compounds. The unusual combination of properties make the silicone rubbers particularly suitable for sealing compounds under severe ambient conditions. Special compounding ingredients and procedures were described that made it possible to obtain high tensile strength, excellent tear resistance, 400 degree Fahrenheit heat stability and resistance to oil.

A new family of fusible silicone rubbers was described by J. H. Lorenz and F. Fehete, Union Carbide Corporation. These compounds, fabricated and cured by conventional means, have the unique property of fusing together when pressed or wrapped under slight tension. Heating at moderate temperatures accelerates fusion into a homogeneous mass. In addition, these compounds exhibit a building tack so that they stick to themselves immediately upon application, eliminating the necessity for pressure binding or molds during cure.

Two classes of the silicone rubber fusible compounds were described. The insulating class shows excellent resistance to reversion, good heat stability and high tear strength. It has potential uses in cable wrapping, silicone rubber tapes, hot air duct wrapping and similar applications. The electrically conductive class has a resistivity in the range of 1-2 ohm-cm. This material should have utility as a heat source. Lower conductivity compounds may be formed by blending and used as corona precipitators. This new family of silicone rubber compounds will have applications where the bonding of silicone rubber to rubber, metal, glass or fabric is a problem.

Solvent-resistant fluorosilicone rubbers were described by T. D. Talcott, E. D. Brown and G. W. Holbrook, Corning Corporation. These rubbers combine the high temperature characteristics of silicone rubbers with the oil and solvent resistance of fluorine polymers. Whereas many applications of silicone rubber have been hindered by a lack of resistance to solvents, this new elastomer shows promise in this type of environment.

Polymer Membranes Increase Battery Life

The preparation of characterization of polymeric membranes for the silver peroxide-zinc alkaline cell were described by H. H. Bieber, P. F. Bruins and H. P. Gregor, Polytechnic Institute of Brooklyn. Membranes of ion exchange resins embedded in a vinyl matrix showed low ohmic resistance and were suitable for use as battery separators. Evaluation of these membranes in the silver peroxide-zinc alkaline cell showed that they doubled the cycle life of the cell as compared with the conventional cellulosic separators. Optimum results were obtained with a heterogeneous carboxylic acid type membrane, which increased cell life to at least 350 cycles, as compared with 125 cycles using cellophane. Many of these separators outlived the battery elements; the zinc electrodes required replacement after approximately 200 cycles.

Resins Explored For New Uses

The polyurethane resins were treated extensively at this Meeting. M. E. Bailey, R. J. Fiel, M. E. French and G. C. Toone, National Aniline Division, Allied Chemical and Dye Corporation, discussed the use of castor oil-diisocyanate resins. They prepared coatings of outstanding abrasion resistance, adhesives with bond strengths superior to any known material, potting compounds for encapsulating delicate electronic equipment and foams of varying flexibility and resiliency for shock cushioning.

More detailed reports on the factors important in crash padding were discussed by M. E. Bailey, A. Khawam, G. C. Toone and J. W. Hull, Allied Chemical and Dye Corp. Urethane foam with castor oil as a plasticizer was found to be a better shock cushion than any material presently in use, according to laboratory tests. Lightweight, rigid honey-combed plastics, such as Styrofoam, are actually best for absorbing shocks but they are destroyed by the blow and, therefore, good for only one shot service. Padding materials should be able to return to their original shape after being struck. Foam rubbers are too springy. In tests comparing the castor oil-diisocyanate foam proved best in every respect. In addition to uniformly good shock absorbing properties, the castor oil-diisocyanate foams show low compression set and good resistance to humid aging. Although rate of recovery after removal of the striking object is not as high as in latex foam, it usually is sufficient, particularly in view of the protection it affords.

A paper on modifications of polyethylene resin was presented by L. W. A. Meyer and B. P. Rouse, Jr., Tennessee Eastman Company. A new weather-resistant polyethylene for outdoor use will soon be offered, made possible by recent developments in ultra-violet inhibitors. New higher density polyethylene resins in conjunction with new techniques of forming and molding will eventually permit the use of a wide range of products.

Lithium Finds Heavy Use

A summary of new uses for lithium compounds was presented by R. G. Verdieck, Foote Mineral Company.

"The importance of the unique chemical and physical properties of lithium and its compounds in the fields of lubrication, air-conditioning and ceramic technology has increased tremendously during the past decade," Dr. R. G. Verdieck told the Society's Division of Inorganic Chemistry.

The armed forces can use a single lithium grease in planes over the Arctic and in tanks on the desert, thus solving a tedious supply problem. Such an all-purpose grease is possible because the lithium compound neither stiffens at low temperature nor breaks down at high temperatures, Dr. Verdieck explained.

A second large use of lithium compounds at present is for the manufacture of vitreous or glassy products. The modern television tube uses a glass in which lithium re-

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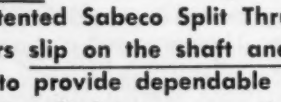

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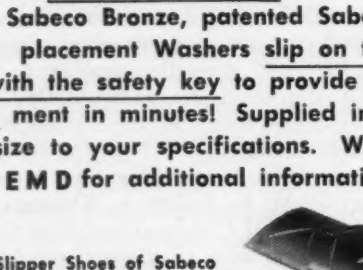

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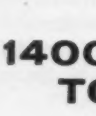

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places the lead found in ordinary glass. This glass, in comparison with the ordinary kind, has increased density and refractive index, and better resistance to chemical attack. It has made possible lighter television tubes, and its lower and wider melting point has allowed the mass production of superior tubes.

The low weight and high heat of burning lithium point to its application in high energy fuels and oxidizers for propulsion of rockets, missiles and aircraft, said Dr. Verdieck. The compound lithium perchlorate, for example, contains more available oxygen in its total weight than does any other compound.

Because lithium-6 produces no radioactive ash, this form of the element is important in the development of a "clean" H-bomb, the chemist reported, and "other nuclear properties of this metal and its compounds indicate potential use as a heat exchange medium and shielding material." Also, according to Dr. Verdieck, scientists hope some day to control lithium-6 as a nuclear fuel in fusion reactors.

Soviets Found Pampering Inventors

American scientists and engineers have an enormous curiosity about their opposite numbers in the Soviet Union. Much has been heard recently about the training, incentives and status of Soviet scientists and engineers.

How the Soviet Union, in its scramble for technological progress, spurs inventors with "all sorts of prizes, praises and promotions" was described by Mordecai Hoseh of Washington, D. C., assistant editor of the Society's publication *Chemical Abstracts*.

Under Soviet law, an inventor may seek protection under either a patent or a certificate of authorship. If he obtains a patent, he enjoys sole rights to his invention and can license it on his own terms—unless it turns out to be of special importance to the state. In that event, the state may order "mandatory alienation" of the patent or force the owner to issue a license to a government agency at a fee fixed by the state.

The holder of an author's certificate transfers the invention rights to the government in the first place, and receives an honorarium fixed by the state. Theoretically, each inventor may request either a patent or a certificate, but in practice, Mr. Hoseh said, "Soviet citizens are discouraged from requesting patents, and inducements are offered to choose author's certificates instead."

The benefits from a patent are found in licensing fees or, if the patent is alienated by the state, in the fee fixed by the government, the speaker explained. An applicant for a patent has to pay a fee, however, and his income from licensing is taxable.

Holders of certificates enjoy other privileges than the honorarium fixed by law, according to Mr. Hoseh. Some of these privileges start almost at the beginning, since applicants for certificates need pay no fees.

"If the invention needs perfecting or further experimentation," Mr. Hoseh continued, "time and facilities are offered free to the inventor to complete his invention. Payments received for an invention or suggestion for technical improvement are not taxable, or only at a reduced rate. Inventors have a priority in promotions. Generally, the Soviet government through its ministries and their subdivisions greatly encourages 'inventiveness' through all sorts of prizes, praises and promotions."

Patent literature is about the hardest of all Soviet literature to obtain, Mr. Hoseh reported. A probable reason, he suggested, is that patent literature has a very limited and highly specialized circulation in Russia itself, and lack of profit motive, coupled with the language difficulty, greatly reduces the incentive for marketing such publications.

STAFF COLUMNIST

Israel Katz

Israel Katz is manager of Liaison and Consulting Engineering at General Electric's Advanced Electronic Center.

Oil cans to missiles

At the SAE National Aeronautics meeting in Los Angeles last month, it was evident that curious pressures were being felt in aeronautical circles. The fast pace of technological developments and the growing gap between advances in the art and related boundaries of knowledge added spice to the flavor of papers presented at the conference. Four of these papers are reviewed here because of their interest to electromechanical designers.

"Systems Analysis Approach to Firebee Flight Control System Development." C. D. Corden and H. J. Hansen, Jr., Ryan Aeronautical Company.

The recorded experiences of Corden and Hansen in the development of the firebee drone flight control system brought to mind anguished moments with such things as dutch roll, phugoid motions and short-period pitching. The statement, "We found that by conducting simplified flight in the laboratory, various 'bugs' that turned up during actual flight test could be duplicated systematically," is a classic. In this discovery they do not stand alone.

Their systems approach to control system development is not the only possible one, but if we are to achieve effective automatic control of complex high-speed flight vehicles, from both airborne and ground-based control centrals, a systems approach as described gives the greatest flexibility and permits the kind of iterative analysis which seems almost essential to closed-loop control system development.

One of the sage conclusions to be drawn from the paper is that an oil can often is a good thing to have around since the road to development failure is paved with unlubricated electromechanical gadgetry.

"On the Protection of Airborne Equipment Against Shock". C. E. Crede, Barry Controls, Incorporated.

Mr. Crede set forth several intriguing hypotheses concerning factors affecting the failure of equipment when subjected to shock. Reasons for failure of electromechanical equipment exposed to severe shock are not understood fully. Satisfactory techniques for reducing pertinent data into meaningful information don't exist. With the increase of shocking levels and the accuracy requirements of equipment, the need for better understanding of shock failures and the establishment of design criteria for the resistance of equipment to intense shock becomes critical.

The well-known inadequacies of shock test equipment were discussed, particularly from the standpoint of their inabilities to divorce the effects of shock on a specimen being tested from side effects of the same shock on the test equipment. Mr. Crede described the typical application of single-degree-of-freedom analogs to two and three dimensional shock spectrum situations and the related benefits and limitations, particularly where the shock loads are applied cyclically. Where the shock load is singular but intense, as may occur in airborne equipment when a cannon attached to the airframe is fired, existing methods of shock-effects analysis are inadequate and satisfactory design criteria do not exist. Mr. Crede maintained that not until present shock failure hypotheses have been substantiated by experiment and field experience can confidence in designing for adequate shock resistance be realized.

"Packaged Hydraulic Systems for Missiles". A. L. Stone and J. W. Woodward, Vickers, Incorporated.

The paper discussed the effects of missile weight and space limitations on the design and functions of electromechanical devices associated with missile propulsion equipment and control systems.

Many designs have yielded to almost unreasonable pressures for flexibility, large capacity, low weight and small bulk. For example, components now are expected to perform multiple complex functions and Herculean tasks despite their midget proportions. Much has, and can be done in miniaturization. Although the trend may continue with certain noteworthy increases in component reliability, the paper did not focus sufficient attention on the limitations to miniaturization resulting from the physical properties of materials and the inherent characteristics of given species of electromechanical devices.

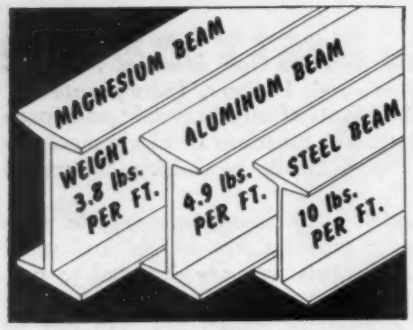
It is true that a measure of success in miniaturization and the performance of combined complex functions by equipment has been achieved, but it is necessary to be mindful of predictable effects of operating variables on the terminal performance characteristics of equipment and the real limitations imposed by physical laws. There is a great need for miniaturization, experience, and ingenuity in design, but also for a clearer understanding of all the factors at play in complex systems.

"Requirements of the Missile Industry for Accessory Power". R. D. Boyne, Aircraft Accessory Turbine Department, General Electric Company.

This was an exceptionally clear insight to the prevailing garbled understanding of the forces at play in many advanced development areas. Mr. Boyne believes that much greater lead time for the development of accessory equipment than is now permitted is essential if over-all missile system developments are to be successful. Recent events seem to bear him out, but it is doubtful whether an increase of lead time (and the resulting reductions in development schedule pressures and manpower requirement) together with an elimination of backup programs will increase the probability of development success.

Not brought out in the paper is the concept that because missile art is quite advanced, the expenditures of money, time and effort tend to yield only marginal returns and, as a result, the vast outlay of manpower and resources over an extensive period of time is necessary to realize substantial advances in the state of the art. Mr. Boyne demonstrated strikingly that vendors of accessory equipment to the missile manufacturers are almost hopelessly trapped by a combination of tight money, changing technical requirements, manpower deficiencies, conflicting specifications, soaring costs, hazy contractual requirements, manufacturing headaches of all kinds and too many cooks.

The discussion of accessory power devices was in reality a vehicle for illustrating the problems that burden the accessory device industry. While Mr. Boyne's related thoughts on the matter may not serve completely to rectify the situation, they are suggestions in the right direction. He suggested that design and performance requirements for accessory devices be established, much earlier in an overall missile program; that more development money be allocated for state-of-the-art advancements in missile accessories; that the military should critically evaluate the ability of accessory manufacturers to demonstrate feasibility of their devices within the specified time; that more time be allocated for product design in a given missile program; that industry should be furnished with better information on equipment test facilities, and that prime contractors be more circumspect in selecting accessory device vendors and that they place greater emphasis on the reliability of hardware even at the cost of moderate penalties in equipment performance and sophistication.



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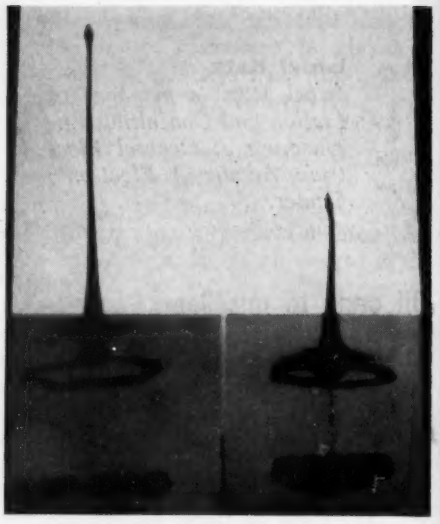
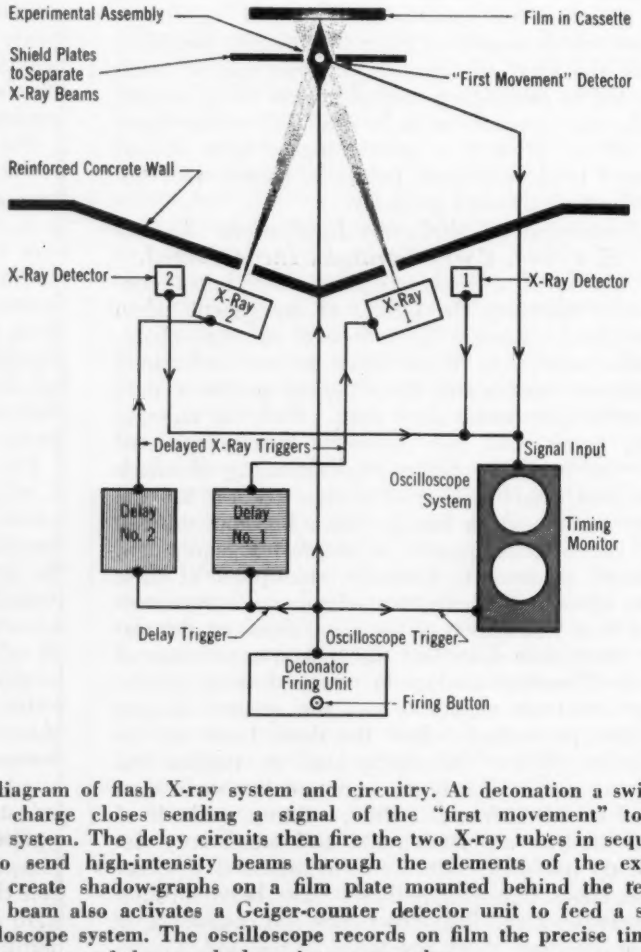
Through the smoke and flame of an explosion, flash X-ray equipment reveals valuable information about shape changes and velocities of explosive assemblies, charge casings and other components. Shape and position of the test charge and its components during the explosion plus exact duration of action provide explosion rates and velocities.

In shooting an explosion, two pictures of one charge provide more valid data than pictures of separate charges with different compositions. Two X-ray tubes coupled with a high-speed camera (up to one ten-millionth of a second exposure) fire in pre-set sequence sending high-intensity beams through the exploding test charge to a film plate. The system records two shadow pictures or radiographs of the explosion on film mounted up to four inches from the charge. Simultaneously, the precise times of the start of the explosion and of each picture are also recorded on the 35 mm film. From this information engineers compute the rate of change of elements in the explosion.



Shadow pictures of test explosion of a shaped jet charge made with X-ray flash.

The test facility consists of a reinforced concrete, bombproof shelter with one steel-covered wall depressed into the shelter in the form of a shallow V. This V-shape permits beams from



Schematic diagram of flash X-ray system and circuitry. At detonation a switch attached to the test charge closes sending a signal of the "first movement" to the sweep oscilloscope system. The delay circuits then fire the two X-ray tubes in sequence at pre-set times to send high-intensity beams through the elements of the exploding test charge and create shadow-graphs on a film plate mounted behind the test assembly. Each X-ray beam also activates a Geiger-counter detector unit to feed a signal to the sweep oscilloscope system. The oscilloscope records on film the precise times at which the explosion starts and the two shadow pictures are taken.

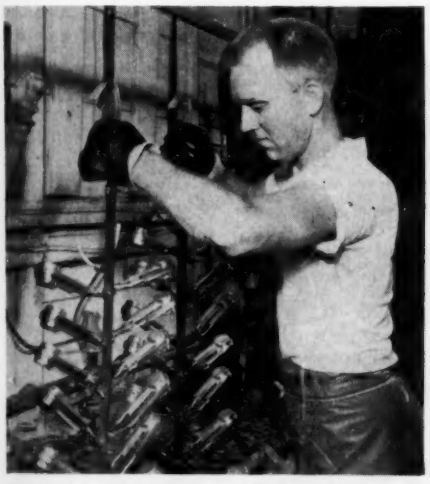
the two X-ray units, directed through wood panel "windows" in the wall, to converge on the test charge mounted outside the wall. The arrangement permits photographing the same explosion from different angles at the same distance and at two different times in rapid sequence.

Vertical shielding plates are positioned on each side of the charge mount to limit the area of film exposed by each X-ray beam to half the film plate. This allows two pictures to be made side by side on the same plate for easy comparison.

The film is protected by encasing it in metal cassettes, or frames, and covering it with wood and aluminum panels. To prevent explosive forces from damaging the film, the relatively light cassettes are positioned so they can be blown away by the explosion. Poulter Laboratories, Stanford Research Institute, Menlo Park, Calif.

Circle 166 on Inquiry Card.

COPPER PLATING



M&T BRIGHT CYANIDE COPPER plating process uses a new combination of additives to reduce plating costs and simplify control. The process also promises fast plating speeds, improved brightness and other advantages on all common base metals. M&T Neochel, a new bath additive replacing Rochelle salt, minimizes anode corrosion and rough deposits. Two brighteners and a wetting agent comprise the other additives.

The solution can be made up with either sodium or potassium salts. Permissible cathode current densities range from 10 up to 60 ASF. A wide bright plate range at high cathode efficiency assures fast deposition without burning on edges or dullness in recessed areas.

Cost of operation is favorable because of the long life and stability of the addition agents. Stability of the proprietary materials eliminates product decomposition in the bath. Only one chemical determination and a single Hull Cell test are required to control additives. Metal & Thermit Corp., Rahway, N. J.

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during normal operation
POSITIVE LOCKING . . .
at power cut-off
With New One-Way Torque Bearing

Power Source — **SMITH-NOBAK DEVICE** — **Driven Load**

The Smith-Nobak Device permits both shafts to rotate simultaneously. When power stops, the device prevents further rotation of the mechanism either from the initial inertia force or from an external force applied from anywhere except the original source. The driven shaft is locked in position to prevent its rotation in either direction. Application of power unlocks the device instantly.

The device is finding numerous uses in automation, aircraft control mechanisms, hoists, transfer tables, conveyors, punch presses, printing presses, and wherever a positive control of angular position is required. It is especially adaptable for steering mechanisms of industrial trucks, tractors, and boats; for feeds into presses, and for boom hoists of derricks. Load ratings from 50# in. to 2600# in. are available. Specific recommendation will be sent you on receipt of your requirement.

4-page Smith-Nobak bulletin and technical data available on request. We also manufacture special ball, roller and thrust bearings to meet customer requirements.

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Elasco's MINISOURCE power supplies, fixed or semi-variable, are designed for use with transistorized circuits, instrumentation, computer circuitry, as bias supplies, or any application where good regulation of low voltage is required. They are available for either 60 cycle or 400 cycle operation, for *any* voltage between 4 and 50 volts, and at current ratings between 50 and 500 ma:

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CIRCLE 60 ON INQUIRY CARD

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Concentricity: No More, No Less

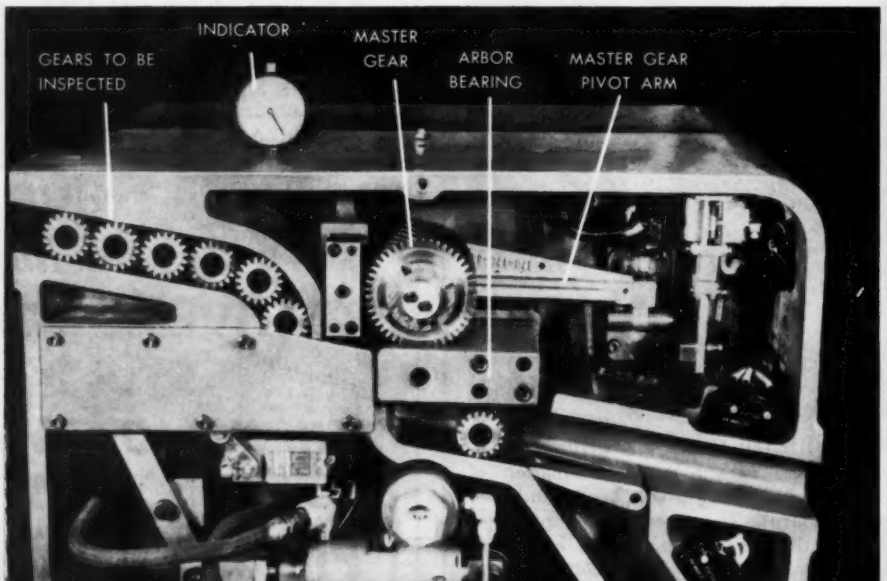
An automatic gear monitoring unit inspects spur or helical gears for concentricity, passes parts within predetermined tolerances, and shunts others from the system. Conjugate rolling action of a master gear in mesh with a gear being inspected transmits concentricity information to preset controls for appropriate action.

Complete concentricity-checking cycle per gear is six seconds with accuracy of tolerance adjustment limited only by error in the master gear and reading of the indicator when limits are set.

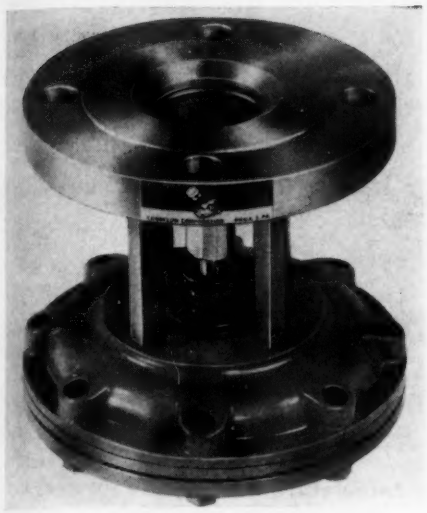
The unit, initially designed for short planetary gears of automatic transmissions, is available in a range of sizes to suit automotive and other gears. It is designed for integration into automated production lines with electrical operation from a central control panel. Operation of the equipment is illustrated.

Allied units consist of a blow-off device to clean the gears, a probe-type size checker or "3-way" classifier to reject over and under-sized gears, and a parts elevator to feed the concentricity checker. Michigan Tool Company, Detroit, Michigan.

Circle 165 on Inquiry Card.



Gears in process of inspection. Gears enter concentricity checker by gravity and roll into shuttle slide. Advancing shuttle meshes part with master gear and trips a limit switch to actuate a push-type diaphragm arbor. The arbor enters, adapts itself to the hole size of part, and holds it under and in mesh with master. Part is first rotated clockwise in mesh with master. Pivot arm of master raises a slide assembly to high limit of eccentricity of part in which position the slide assembly locks and pivot arm makes contact with a micro-switch. Part is then rotated counterclockwise. If a predetermined amount of eccentricity or more is present pivot arm of master drops enough to break contact with the micro-switch and allow reject chute to open. If contact with the micro-switch is not broken, gear is accepted and rolls down skew loader for other processing. Indicator gage is mounted on top of the unit.



Pressure and Liquid Level Transmitter

A newly designed pneumatic pressure and liquid-level transmitter measures pressures as high as 250 psi or ranges from as low as 0 to 100 inches of water. Operating on the simple force-balance principle, the unit transmits a linear 3-15 psi signal to a recorder, indicating gage or manometer. It is especially suitable for those services involving viscous fluids or materials that would solidify in conventional pressure transmitters. It can be mounted either horizontally or vertically on both open and closed tanks. No dip tubes, floats or other mechanical devices are required inside the vessel. Only the corrosion-resistant Inconel X diaphragm is wetted by the measured material. The transmitter design eliminates the possibility of measured material backing up into air lines in the event of pressure diaphragm rupture. Ranges can easily be changed in the field. Conoflow Corp., Phila., Pa.

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WORTH FILING

V-Belt Drives

108-page manual gives comprehensive information on selection and operation of V-belt drives. Sections cover standard, variable-speed and special drives, taper-lock sheaves, sealed-life V-belts, and taper-lock bushings and hubs. Engineering drawings and exploded views illustrate technical sections of the bulletin, which contain comprehensive tables of pre-engineered drives, making the selection of a complete drive quick and easy. Other tables give horsepower capacities, belt speeds, center distances, sheave diameters, and other data when special drives are required. Indexed for convenient reference.

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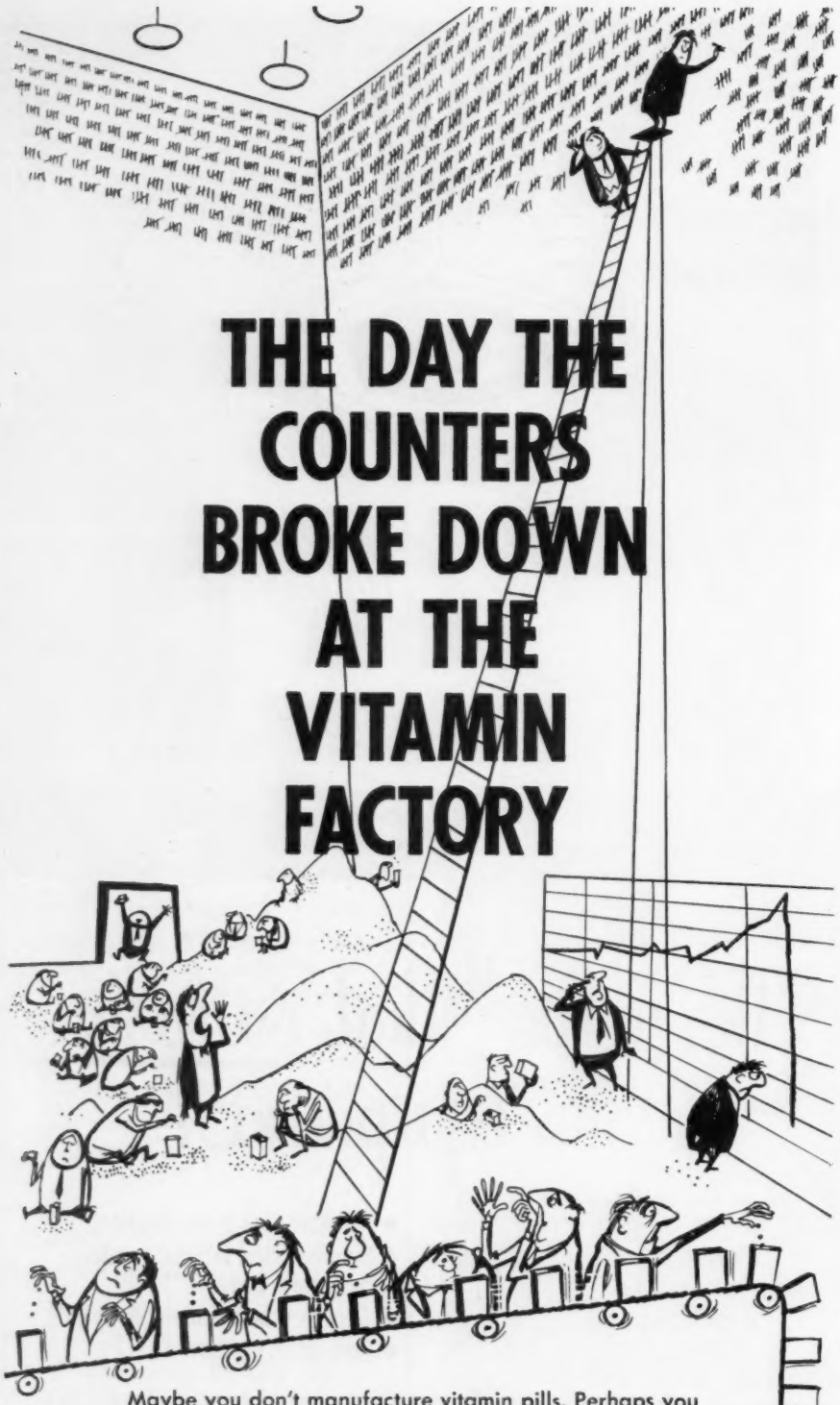
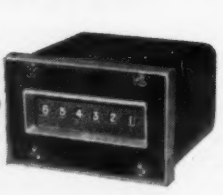


THE DAY THE COUNTERS BROKE DOWN AT THE VITAMIN FACTORY

Maybe you don't manufacture vitamin pills. Perhaps you can't even swallow one. But you may have a similar complex counting problem the ordinary Counter can't solve. If so, the Autron *NEURON* Counter might be the answer, as it was for Operation Vitamin (see above). It subtracts as well as adds (see below).

The "NEURON" counters epitomize the most advanced electro-magnetic counter technology, featuring high speed (to 60 PPS), long life (in excess of 300 million cycles), pulse reset, switch readout, bi-directional drive (add and subtract), and small size. These precision units may well be the answer to your tabulation problems.



Autron
ENGINEERING, INC.

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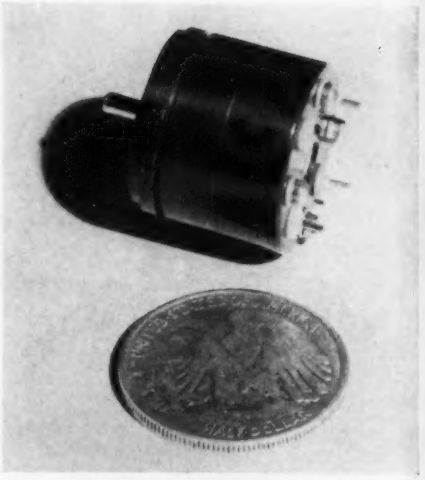

Subminiature Microsyn

A self-contained microsyn, approximately one inch in diameter, one inch long, and 1.2 ounces in weight, has a sensitivity of 500 millivolts per degree with a threshold of 0.01 degree at 20 volts excitation and linearity within 0.5 precent to 7 degrees. Intended for use wherever there is need for accurate translation of angular displacement into electrical signals, these miniature units may be used in such applications as position-indication of gyros, control follow-up devices, computation, process control, motion and torque amplification. Lear, Inc., Grand Rapids, Mich.

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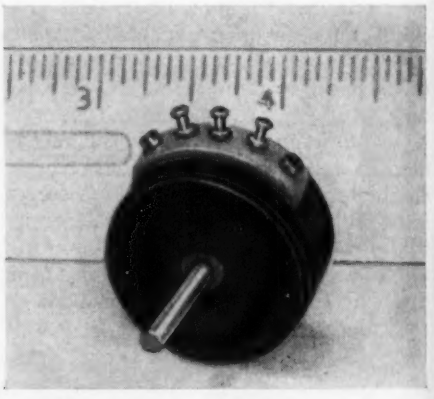

Compact Precision Pot

High resolution and linearity, with resistance ranges from ½ ohm to 350 K ohms, in a space only 1-1/16 inches diameter by ½ inch deep make the new Waters WP 1-1/16 precision potentiometer especially useful for linear and non-linear applications in miniaturized apparatus. Standard linearity is 0.5 percent and linearities of 0.25 percent and better can be attained on most specifications. Housed in an anodized aluminum case, shaft diameter is 1/8 inch. Turret-type terminals are mounted on a fungus-proof insulating board of Epon-glass laminate. Special mechanical accuracies for the shaft and pilot orientation are possible. Waters Manufacturing, Inc., Wayland, Mass.

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COMPONENTS

Infrared Meniscus Lenses

New single-element infrared lenses, designed to give optimum performance under conditions where achromatic imagery is not required, have minimum spherical aberration when imaging an object at infinity at a dominant wavelength of 3½ microns. They have reasonably good performance from 2 to 5 microns and good transmisison from 1 to 12 microns. Anti-reflection coatings are available for any specified wavelength in the 1 to 6 micron range. Designs include focal lengths from 2 to 12 inches at relative apertures of f/2.0 and f/4.0. Servo Corporation of America, New Hyde Park, New York.

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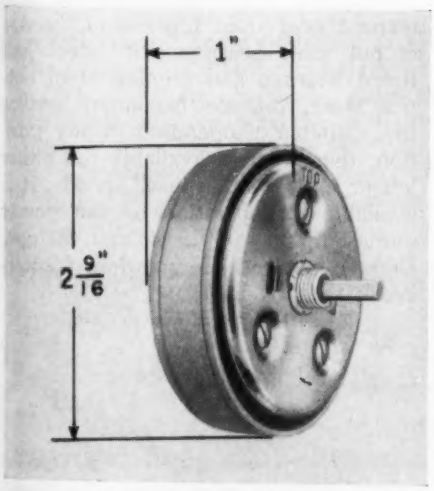

Miniature Bell Timer

Rugged, miniature "Mark-Time" Bell Timer, designed for "built-in" timer application, can be mounted in locations where space is not available for the conventional size units. This timer is adaptable to a variety of industrial equipment or appliances where a clear, resonant bell signal is desired at the end of a specific time period. The timer is available in timing ranges from 60 seconds to 5 hours. M. H. Rhodes, Inc., Hartford, Conn.

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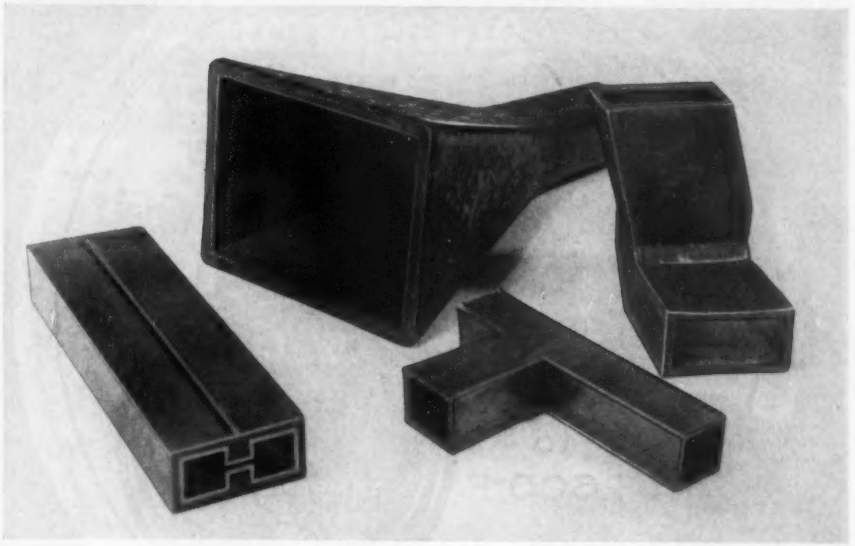
Electroforming



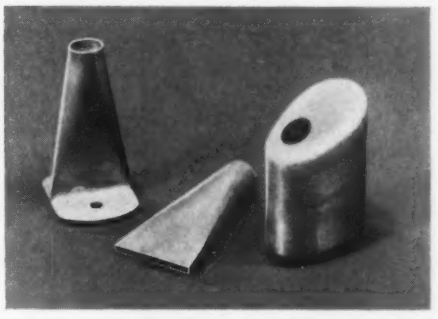
Laminates of metal to metal can be produced in various thicknesses by depositing one metal over another.

New Latitude in Design

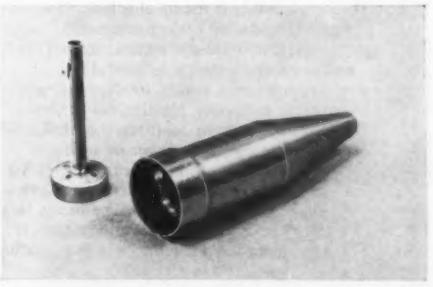
Improvements in electroforming, a relatively new production technique, now permit this process to be applied to the production of high precision electro-mechanical components. It is now used in the production of metal shapes, especially those of tubular, conical or cup-like parts, more economically than by deep-drawing or other operations involving more than a simple swedging or stamping.

Basically the electroforming process involves the electrodisposition of a layer of metal on a master mandrel and the subsequent removal of the plated shell so that a self-supporting part or formed article, not a mere coating, is produced. In forming complicated shapes that involve undercuts, the mandrels are made of low melting alloys that can be melted out in a hot oil bath. Electroformed interior surfaces achieve highly reflective mirror finishes without polishing and produce an extremely high degree of density without porosity.

High precision parts are now being electroformed from nickel, copper, iron, silver, lead, tin, cadmium, zinc, cobalt, indium, and chromium.



Instrument float made in one piece with a wall thickness of 0.005" eliminates the need for any welding or soldering operations normally used in joining halves.



Left: Pendulum for gyroscope concentric within 0.001".

Right: Magnetron cathode support made of high-purity electrolytic nickel.

Feel free to send us prints or samples for our engineering comment and quotation. No obligation or charge, of course.

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THE STATHAM MODEL TC-4 portable Temperature Test Chamber has proven its versatility and value for years in such fields as the Aircraft, Electrical, Electronic, Automotive, and Chemical industries. Its wide operating range—from −75°F to +600°F makes it the ideal solution for testing small products, basic instruments, electronic subassemblies, transistors and semiconductors, mechanical components, paints, foods, dyes, textiles, organic materials, plastics, rubber, etc.

Among its many features, the Model TC-4 Temperature Test Chamber offers an economical solution to product testing as well as freedom from delays, attendant upon scheduling time in the larger test chambers. Accurate adjustable temperature control, wide temperature range, and a product capacity of 600 cubic inches provide the most versatile test chamber available for your testing needs.

If parts or materials must be tested at both high and low temperatures, the use of two chambers will greatly reduce the amount of time required for the test. One chamber can be maintained at the desired high temperature, while the other can be kept at the low temperature. The materials may simply be transferred from one chamber to another with no loss of time in varying the temperature of a single chamber.

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WINDOW TRAYS Also available are Window Trays, which allow visual inspection or photographing of the product under test.

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Miniature Synchronous Motor

A new permanent magnet synchronous motor rated 60 inch ounces at 1 rpm has been designed for application in high speed controllers, counters and metering devices and is available in speeds from 72 rpm to 2 rpm. It has low input (2.5 watts), small size (1-5/16″ depth dimension) and a maximum temperature rise of 35°C. Reaching synchronous speed within 2 cycles of powerline frequency, this motor also provides instant stop due to low rotor speed (240 rpm on 60 cycles) and magnetic braking effect. Its inherent accuracy is obtained through a precision gear train composed of hobbed gears and steel pinions bearing on high carbon steel studs driven into heavy gage brass plates. Oilite rotor bearings with a built-in lubricant reservoir, permanent gear train lubrication, bronze output shaft bearings with steel ball thrust bearing, and stainless steel output shaft, provide maximum service life. Capable of operating in any position, the motor is available for either left or right rotation in all speeds. It is available for operation on a-c power sources up to 250V., 60 and 50 cps. Cramer Controls Corporation, Centerbrook, Conn.

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Semi-Adjustable Time Delay Lines

The delay length of this new delay line may be specified by user and is adjustable over a range of 5 micro-seconds. Adjustment is made by turning a sleeve along the threaded body. Intermediate pickoff may be specified as required. Body diameter is 1⅛ inch maximum, while length of tubular casing depends on the delay factor. Deltime, Inc., Mamaroneck, N.Y.

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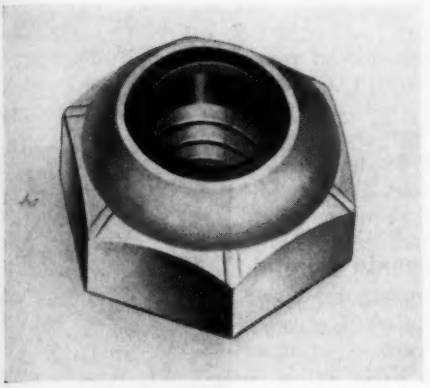

NEW LINE OF GRC NYLON INSERT LOCKNUTS has die-cast zinc alloy hex nut body and molded nylon compression collar for locking element. A new manufacturing approach firmly anchors the unthreaded nylon collar in the nut body preventing the collar from turning or breaking out. The nylon collar tends to return to its original shape when removed from the screw permitting reuse without appreciable reduction in locking torque. The nylon locking element maintains a constant grip on the screw threads, dampens vibration, seals out moisture, and resists loosening. Locking effect exists at any point along a mating screw even if not tightened down against a seating surface. This new locknut will not cause damage to mating screw threads.

The die-cast nut body is rustproof corrosion resistant zinc alloy and can be used for most indoor or outdoor applications without a protective finish. The nylon molded collar is impervious to practically all chemicals, solvents, and weathering condition. Gries Reproducer Corp., New Rochelle, N. Y.

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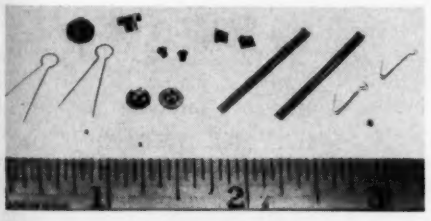

Precious Metal Wire

Precious metal wires for resistance windings are now available down to diameters as small as 0.0005 from The J. M. Ney Company. The two wires available are Ney-Oro G, a gold-platinum-silver-copper alloy with a resistivity of 80 ohms per CMF; and Paliney #7, a palladium-platinum-gold-silver-copper alloy with a resistivity of 200 ohms per CMF. Both wires are furnished bare or enameled, as sliding contacts or wipers, and in standard wire forms or to specifications.

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10 STANDARD CLUTCHES

to cut your costs!

for OVER-RUNNING BACKSTOPPING • INDEXING

Proven in hundreds of applications—Time after time Precisionspring Over-running Clutches have outperformed other clutches at higher speeds with longer life and less maintenance—at lower cost.

10 standard models now in stock—Today you can get all the advantages of Precisionspring Over-running Clutches *right off the shelf.* Standard models in 8 to 200 lbs.-in. torque capacities are available to help you improve your product by replacing the clutching device now being used.

Get your copy of Bulletin SP-20—If you are now producing any kind of mechanism that must overrun, backstop or index you will want to check all the facts about these cost-saving Standard Precisionspring Clutches. Bulletin SP-20 gives complete engineering information. Write to the home office, 1145 Galewood Dr., Cleveland 10, Ohio—or phone GLenville 1-4800.

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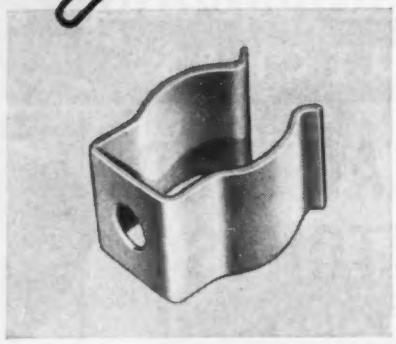

BIRTCHER TRANSISTOR CLIPS

MATERIAL
Beryllium #25

FINISH
Choice of Cadmium, black Ebanol or Silver plated

SIZES
Available in sizes and modifications to retain all popularly used transistors.

Birtcher TRANSISTOR CLIPS perform the dual functions of retention and heat reduction. Being made of tempered beryllium copper they grip the transistor securely and hold it in place even under severe conditions of shock and vibration. In addition they provide an excellent heat path to drain off heat into chassis or heat sink.

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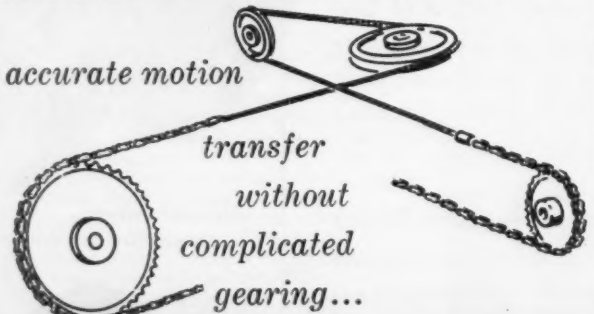

SIERRA MINIATURE MECHANICAL CHAIN AND SPROCKETS...

Provide precise, positive motion transfer through several planes simultaneously with no cable slippage...no complicated gearing. Unlimited center-to-center selection for miniature and sub-miniature assemblies in servo systems, gyro systems, special cameras, electronic equipment, and small precision instruments. Less weight, cost, maintenance —wider tolerances. Designed to operate around minimum 7-tooth sprocket with root diameter of .250 inches. Chain pitch .1475 inches; Weight .45 oz. per lineal ft. Material: stainless steel, or other materials, including non-magnetic beryllium copper.

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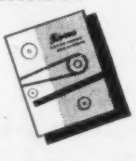

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FOR MORE INFORMATION CIRCLE 66 ON INQUIRY CARD

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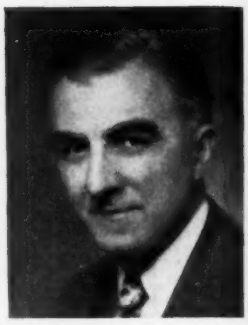

Renato Contini

Renato Contini is Research Coordinator at New York University's College of Engineering.

HUMAN FACTORS IN DESIGN

In any engineering field, particularly in the aeronautical, electrical and mechanical, it is desirable for the engineer to become acquainted with the work now being done in the area of Human Factors. It is especially important that design efforts where man is a consideration be integrated with the efforts of the psychologists, physiologists and other life scientists engaged in Human Factors Research.

Considerable activity is taking place leading to this end. For a number of years the Ergonomics Research Society has been in existence in England. This group has held a number of meetings to which scientists from the United States have been invited. The Society is inter-disciplinary in scope, although the present emphasis seems to have been directed towards the medical and physiological factors involved in man-machine and man-environment problems. The first issue of the Society's new International Quarterly Journal is due this month (November. The Journal will be available in the United States through the Academic Press, Inc., 111 Fifth Avenue, New York 3, N.Y.).

In September, a meeting was held in Tulsa, Oklahoma, for the purpose of organizing the Human Factors Society of America. The Society was conceived in June 1956 when a group of Southern California engineers, psychologists, physiologists, anthropologists, medical doctors and other specialists met for this purpose in Los Angeles. As stated in its Constitution, the Society "has been organized to increase and diffuse the knowledge of man-machine factors in all its ramifications, pure and applied, to promote the mutual interests of investigators of man-machine-environment problems, of supporting sciences, of designers, manufacturers and users of products and apparatus of all kinds related to man, and to encourage cooperation among them." The HFSA proposes to publish a Journal starting July 1958. The address of both the Society and the Journal is Box 24032, Los Angeles, California.

These are the two major organizations in England and in the United States active at the present time in this area of specialization. An international group interested in Work Science has been considered. There are furthermore a number of groups interested in this work within already existing scientific professional societies.

A group of experimental psychologists experienced in this area organized about a year ago the Society of Engineering Psychologists as a division within the American Psychological Association. This year, this group was officially recognized as Division 21. Although the membership consists principally of psychologists, other scientists interested in the field of Human Factors may become associated with

this Division. Information may be obtained from the American Psychological Association, 1333 Sixteenth Street, N.W., Washington, D. C.

There are also two groups within the American Society of Mechanical Engineers, 29 West 39 Street, New York City. In the Management Division, a committee on Human Factors in Engineering has been active for some time. In December, it will participate in the Annual Meeting of the ASME in New York and present a number of papers on this topic. Also, a Human Engineering Committee has been functioning within the Aviation Division in Berkeley, California. It proposes to present papers at the Dallas, Texas, meeting of the Division in March 1958.

A series of papers were presented at the Pacific General Meeting of the American Institute of Electrical Engineers late in August 1957. The Fifth Annual Navy Human Engineering Conference was held in Tulsa in September. There is to be a National Symposium on Human Factors in Systems Engineering in Philadelphia, December 3-4, 1957, sponsored jointly by the Human Factors Society, the Institute of Radio Engineers (Philadelphia Section) and the IRE Professional Group on Military Electronics. The American Management Association is conducting a three-day Seminar on Human Engineering in New York, November 25-27, 1957. Other engineering groups have become interested in this field.

With so much activity by so many professional groups in so many sections of the country, it would appear that Human Factors Research and its applications to design problems is obtaining the consideration it should by engineers. Unfortunately, this holds true only in the design of military equipment. It is my hope that eventually the knowledge being developed will be applied to all appropriate engineering design.

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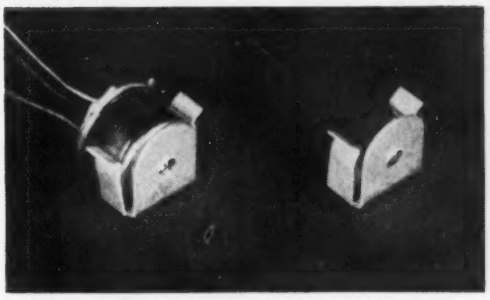

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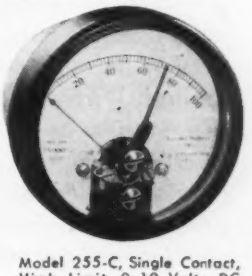

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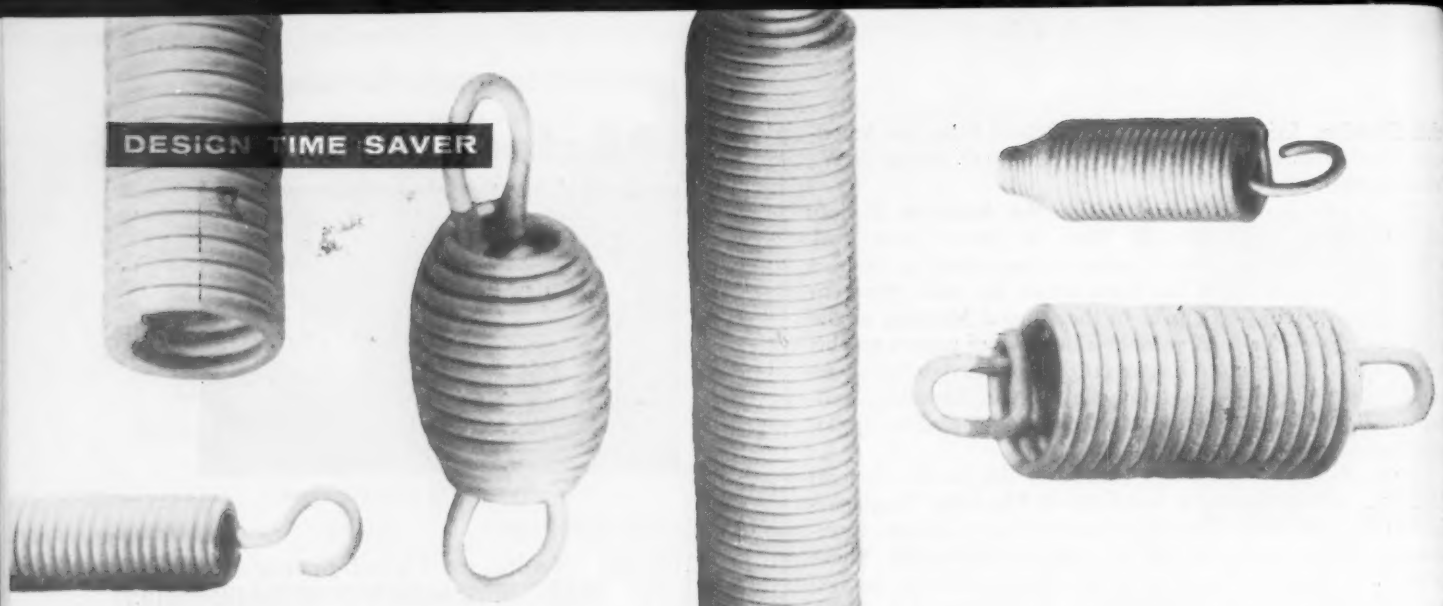
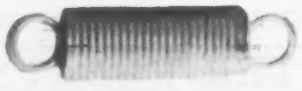
FOR MORE INFORMATION CIRCLE 70 ON INQUIRY CARD

DESIGN TIME SAVER



Precision Extension Spring Design

O. G. Meyers and S. L. Albright HUNTER SPRING COMPANY, LANSDALE, PA.



This is the second of two articles. The first appeared in the September-October 1957 issue of ELECTROMECHANICAL DESIGN and described a simplified method of design for precision compression springs. This article is complete in itself and describes a similar method for the design of precision extension springs. Where it is appropriate to do so, the information in the two articles can be used interchangeably. The spring charts, from either article can be used for either compression or extension spring design. To help you locate information in the two articles it might be stated that, in general:

- *Information pertaining to both types of springs but only to carbon alloy steel wire will be found in the compression spring article*
- *Information pertaining to both types of springs but only to music and stainless steel wire will be found in the extension spring article*
- *Information common to both materials and both types of springs will be in both articles*
- *Information appropriate to the design of only one of the two types of springs will be found only in that article.*

FOR ONE FREE REPRINT OF BOTH ARTICLES
CIRCLE NO. 163 ON READER INQUIRY CARD.

This article presents you with a simplified but complete design procedure for precision, round-wire, close-wound helical extension springs. The design procedure, a step-by-step approach, is simplified in that charts and graphs eliminate much tedious calculation. However, this simplified procedure does not neglect any consideration affecting spring performance in precision applications, as do so many so-called "simplified design procedures."

THE SPRING CHART

Load and deflection values in each square of the Spring Chart represent a unique music wire or stainless steel spring whose wire diameter (d) and outside coil diameter (D) are given at the top and along the edge of the chart. Within the square you will find the spring load (P) listed above, with the deflection per coil (f) noted below it.

The loads indicated are based on a service life of 50,000 cycles at 0.50 stress ratio. For other conditions relating to fatigue life, stress ratio, material, types of end, etc., correction factors are:

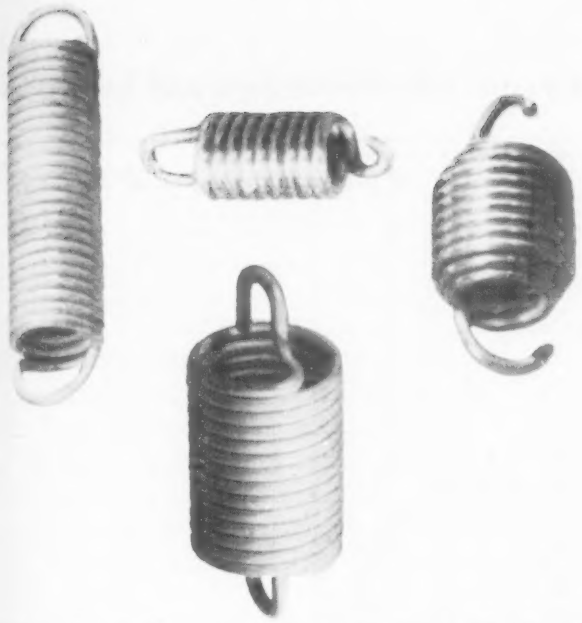
- A—Correction factor for stress range, life cycles, and spring material (Table I)
- U—Correction factor for torsional shear modulus (Table II)
- Ψ—Initial tension factor (Fig. 2)
- R_1—Wahl stress concentration factor (Fig. 3).

The basic stress (S) for each wire size, noted in the right-hand margin of the charts, will be useful in later stages of design. Formulas permit you to interpolate P and f values for intermediate coil diameters within the chart.

EXTENSION SPRING DESIGN PROCEDURE

I. APPLICATION REQUIREMENTS

As with compression springs, you can determine spring forces (initial and/or final loads and the gradient) for any given application by one or more of four commonly



used methods: theoretical calculation, empirical estimation, trial-and-error and direct measurement.

You must make a tentative selection of material before starting the basic calculations for design. Considerations in this selection may include cost, strength and endurance, availability, corrosion resistance, stability at elevated temperatures, and magnetic properties. If you select carbon or alloy steel wire, use the spring chart in the previous article (September-October 1957) on compression spring design.

II. BASIC SPRING CALCULATION

Stress ratio and fatigue life are taken into account by a special treatment of the actual load requirement through the use of the "A" factor (Table I) for the purpose of selecting a proper wire size. This gives a "corrected load" value which is the permissible load for the same spring if operated under the standard "chart condition" of 50,000 cycles and 0.50 stress ratio. An additional factor of 1.3 further compensates for the higher stresses normally encountered in extension spring hooks. This value assumes a hook diameter equal to the coil diameter. If you anticipate a critical space problem, the use of a reduced hook diameter (0.75 times coil diameter) eliminates the need for the 1.3 multiplier and reduces the over-all space requirement. Reduced ends entail additional manufacturing cost which diminishes for greater production quantities.

The first actual selection is made in Step 4 of the design procedure example by turning to the spring chart. When you have established a "corrected load," P_t, the chart blocks having values P equal to or slightly greater than P_t offer you a choice of several springs. From these an optimum O.D., based on space limitations, should determine the most desirable spring.

Before discarding alternative springs, it is well to observe that, in the later stage of design, any single O.D. or wire size selected could dictate an undesirable spring length or some other condition calling for a consideration of other possible O.D.'s. To this extent, the design procedure can occasionally lead to a relatively simple trial-and-error process. As you become more familiar with the procedure, your foresight and ability to make simple mental calculations will help you select correctly the O.D. and wire size (with related deflection-per-coil, f) on the first attempt.

The chart areas left blank represent values of spring index, D/d, that would be of little general interest or impractical to manufacture. When possible, avoid the fringe areas of the chart—the extreme high or low index figures.

A—CORRECTION FACTOR for STRESS RANGE, LIFE CYCLES and SPRING MATERIAL

MATERIAL	$\frac{P_2-P_1}{P_2}$	CYCLES				
		5,000	10,000	50,000	100,000	INFINITE
MUSIC WIRE	.25	1.28	1.23	1.11	1.06	.954
	.50	1.23	1.16	1.00	.928	.762
	.75	1.21	1.12	.928	.845	.652
	1.00	1.17	1.08	.864	.771	.551
STAINLESS STEEL TYPE 302 (18-8)	.25	.918	.899	.835	.807	.771
	.50	.885	.845	.758	.720	.634
	.75	.853	.803	.685	.634	.514
	1.00	.826	.761	.615	.552	.413

Table I

U—CORRECTION FACTOR FOR TORSIONAL SHEAR MODULUS			
Music Wire	1.0	Stainless Steel	.833

Table II

HOOK TYPE		NOT LESS THAN	NORMAL	NOT MORE THAN
	1	Use Normal	ID	Use Normal
	2	Use Normal	ID	Use Normal
	3	Use Normal	½ ID	Use Normal
	4	Anything greater than ½ ID	L	1.1 ID
	5	1.1 ID	—	.5 ID*
	6	No Limit	No Limit	No Limit
	7	1.1 ID	—	No Limit
	8	.5 ID	—	—
	9	.5 ID	—	No Limit
	10	4 wire sizes minimum	—	No Limit

* This might not apply for large indexes. Consult manufacturer.

Table III—Length limits for common extension spring hooks.

The load, P, is that taken from the spring chart—a value equal to or just greater than the required P_t. Directly below it, in the same chart block, is the deflection per coil, f, in inches, to be used later in calculating number of coils for a given gradient, K, or deflection, F, for a fixed number of coils. At the far right of the chart is the basic stress, S, in thousands of pounds per square inch. The factor U—correcting for torsional shear modulus of the material—is given in Table II.

A certain angular relationship is often desired between the ends of an extension spring. The number of active coils as computed from the tabular data in Step 5 will rarely

Spring Charts: LOAD AND DEFLECTION VALUES FOR COMPRESSION AND EXTENSION SP

WIRE DIAM.	OUTSIDE DIAMETER OF SPRING — PREFERRED NUMBERS																																
*d	.040	.050	.060	.070	.080	.090	.100	.120	.140	.160	.180	.200	.220	.240	.260	.280	.300	.320	.340	.360	.380	.400	.450	.500	.550	.600	.650	.700	.750	.800	.850	.900	.950
.008	.6747 .06259	.5594 .00573	.4757 .01007	.4120 .01451	.3624 .01998	.3249 .0265	.2934 .0338	.2463 .0511	.2124 .0709	.1866 .0968	P f																						
.009	P f	.7722 .00541	.6623 .00894	.5750 .01327	.5095 .01854	.4546 .0246	.4121 .0316	.3460 .0481	.2982 .0682	.2623 .0918	.2340 .1198																						
.010		1.046 .00446	.8972 .00572	.7841 .01129	.6942 .01580	.6218 .02122	.5618 .0273	.4730 .0420	.4082 .0598	.3589 .0800	.3202 .1040	.2892 .1322																					
.011			1.167 .00625	1.026 .00959	.9105 .01361	.8170 .01834	.7411 .0238	.6236 .0358	.5377 .0525	.4727 .0712	.4206 .0924	.3812 .1172	.3477 .1445																					
.012			1.496 .00532	1.313 .00824	1.171 .01184	1.054 .01588	.9574 .0210	.8056 .0326	.6953 .0468	.6115 .0638	.5461 .0833	.4934 .1054	.4500 .1302	.4136 .1576																				
.013				1.640 .00709	1.465 .01020	1.319 .01406	1.201 .01845	1.012 .0299	.8759 .0419	.7701 .0571	.6876 .0747	.6214 .0948	.5670 .1174	.5214 .1423	.4823 .1696	.4487 .1993																		
.014				2.009 .00612	1.791 .00894	1.628 .01240	1.479 .01663	1.254 .0258	1.079 .0375	.9517 .0514	.8504 .0675	.7686 .0850	.7016 .1064	.6448 .1292	.5967 .1542	.5555 .1814	.5196 .2109																	
.016					2.605 .00805	2.359 .00973	2.160 .01303	1.837 .0210	1.591 .0309	1.3996 .0425	1.254 .0563	1.131 .0717	1.034 .0893	.9512 .1088	.8804 .1301	.8205 .1536	.7669 .1787	.7205 .2060	.6792 .2350															
.018						3.276 .00776	2.989 .01047	2.564 .01720	2.237 .0258	1.972 .0358	1.760 .0475	1.595 .0611	1.454 .0762	1.339 .0931	1.240 .1115	1.154 .1310	1.080 .1539	1.015 .1776	.9576 .2038	.9058 .2301	.8590 .2588													
.020							4.016 .00857	3.445 .01436	3.011 .0217	2.666 .0305	2.388 .0408	2.157 .0524	1.975 .0659	1.816 .0806	1.683 .0988	1.567 .1149	1.466 .1341	1.378 .1551	1.299 .1774	1.230 .2014	1.167 .2268	1.110 .2539											
.022								4.481 .01200	3.936 .01841	3.495 .0281	3.134 .0352	2.843 .0456	2.593 .0573	2.394 .0706	2.216 .0850	2.062 .1008	1.931 .1181	1.816 .1368	1.713 .1568	1.622 .1782	1.538 .2009	1.464 .2250	1.306 .2914									
.024								5.701 .01814	5.002 .01570	4.462 .0226	4.016 .0288	3.646 .0480	3.332 .0584	3.062 .0670	2.939 .0744	2.650 .0854	2.469 .1043	2.331 .1215	2.199 .1395	2.081 .1587	1.975 .1791	1.880 .2008	1.678 .2588	1.514 .3283								
.026									6.232 .01347	5.583 .01988	5.032 .0268	4.574 .0352	4.188 .0446	3.846 .0552	3.571 .0667	3.309 .0797	3.122 .0937	2.935 .1080	2.770 .1251	2.621 .1425	2.488 .1618	2.368 .1837	2.114 .2351	1.908 .2965	1.741 .3654							
.029										7.482 .01586	6.812 .0221	6.209 .0292	5.679 .0373	5.230 .0463	4.862 .0565	4.536 .0676	4.252 .0798	3.998 .0929	3.767 .1069	3.568 .1229	3.386 .1391	3.226 .1553	2.879 .2123	2.602 .2584	2.372 .3163	2.180 .3829						
.031										8.940 .01385	8.083 .01931	7.410 .0267	6.801 .0331	6.287 .0414	5.833 .0506	5.442 .0606	5.098 .0716	4.798 .0836	4.537 .0965	4.285 .1101	4.072 .1249	3.875 .1405	3.459 .1925	3.127 .2328	2.852 .2878	2.621 .3485	2.425 .4151					
.033											9.583 .01711	8.776 .0230	8.085 .0297	7.498 .0374	6.980 .0457	6.488 .0549	6.089 .0651	5.728 .0761	5.410 .0880	5.171 .1007	4.862 .1142	4.630 .1286	4.133 .1684	3.738 .2130	3.410 .2640	3.132 .3209	2.900 .3828	2.698 .4489					
.035											11.28 .01529	10.28 .0205	9.524 .0268	8.800 .0337	8.193 .0415	7.655 .0500	7.178 .0594	6.759 .0695	6.380 .0804	6.050 .0923	5.744 .1048	5.463 .1188	4.886 .1552	4.412 .1971	4.027 .2444	3.701 .2966	3.425 .3540	3.188 .4166	2.982 .4844				
.037												11.95 .01841	11.04 .0241	10.28 .0306	9.560 .0377	8.931 .0456	8.381 .0542	7.894 .0637	7.460 .0738	7.070 .0848	6.715 .0964	6.395 .1088	5.710 .1431	5.162 .1823	4.720 .2262	4.331 .2749	4.010 .3287	3.732 .3878	3.490 .4508				
.039												13.83 .01276	12.73 .0217	11.85 .0277	11.04 .0343	10.33 .0417	9.705 .0497	9.149 .0585	8.642 .0679	8.193 .0781	7.785 .0890	7.417 .1006	6.624 .1325	5.989 .1691	5.467 .2096	5.025 .2557	4.652 .3058	4.332 .3606	4.053 .4198	3.805 .4832			
.041													14.56 .01978	13.54 .0252	12.68 .0314	11.86 .0382	11.13 .0456	10.51 .0539	9.933 .0626	9.412 .0721	8.947 .0822	8.528 .0931	7.623 .1230	6.895 .1573	6.290 .1957	5.784 .2384	5.353 .2852	4.988 .3360	4.666 .3923	4.383 .4521	4.131 .5059		
.043													16.47 .01781	15.24 .0227	14.28 .0285	13.28 .0348	12.48 .0416	11.89 .0493	11.25 .0575	10.59 .0662	10.09 .0757	9.660 .0857	8.650 .1137	7.778 .1454	7.135 .1813	6.559 .2210	6.074 .2649	5.658 .3129	5.291 .3647	4.969 .4204	4.688 .4804	4.435 .5443	
.045														17.26 .0200	16.06 .0259	15.17 .0320	14.26 .0384	13.45 .0455	12.79 .0534	12.09 .0614	11.50 .0703	10.97 .0797	9.785 .1057	8.870 .1358	8.091 .1694	7.448 .2076	6.894 .2481	6.429 .2932	6.008 .3422	5.647 .3950	5.325 .4516	5.037 .5125	4.777 .5778
.047														19.43 .0191	18.08 .0239	16.98 .0293	16.04 .0355	15.13 .0421	14.36 .0494	13.62 .0571	12.95 .0653	12.35 .0742	11.06 .0989	10.02 .1272	9.132 .1588	8.402 .1942	7.782 .2331	7.235 .2758	6.770 .3218	6.375 .3724	6.011 .4253	5.685 .4821	5.385 .5424
.049															20.24 .0220	18.98 .0271	17.97 .0329	16.97 .0391	16.05 .0457	15.26 .0528	14.52 .0608	13.83 .0802	12.41 .0925	11.23 .1192	10.25 .1481	9.428 .1824	8.729 .2192	8.131 .2585	7.613 .3034	7.152 .3504	6.748 .4012	6.381 .4550	6.055 .5126
.051															22.57 .0203	21.11 .0258	19.90 .0303	18.86 .0362	17.89 .0425	17.00 .0494	16.21 .0569	15.45 .0847	13.83 .0985	12.54 .1118	11.46 .1483	10.54 .1718	9.761 .2067	9.082 .2446	8.509 .2863	7.998 .3315	7.539 .3788	7.141 .4305	6.788 .4865
.055																25.87 .0215	24.28 .0268	23.03 .0312	21.87 .0369	20.84 .0431	19.80 .0495	18.94 .0567	17.02 .0764	15.42 .0990	14.05 .1241	12.97 .1530	12.01 .1843	11.18 .2185	10.47 .2559	9.843 .2964	9.283 .3397	8.790 .3863	8.337 .4351
.059																	29.32 .0226	27.65 .0271	26.24 .0329	24.98 .0375	23.94 .0436	22.85 .0499	20.53 .0676	18.63 .0879	17.05 .1111	15.70 .1358	14.55 .1653	13.54 .1963	12.67 .2313	11.91 .2668	11.23 .3059	10.64 .3484	10.11 .3932
.063																		32.83 .0238	31.04 .0282	29.64 .0331	28.37 .0385	27.57 .0444	26.07 .0685	22.20 .0781	20.33 .1002	18.73 .1230	17.36 .1499	16.17 .1783	15.13 .2094	14.22 .2430	13.42 .2973	12.70 .3178	12.06 .3581
.067																			37.15 .0258	35.27 .0274	33.68 .0351	32.26 .0404	29.15 .0542	26.56 .0714	24.35 .0908	22.43 .1124	20.81 .1365	19.41 .1630	18.17 .1915	17.08 .2226	16.10 .2561	15.26 .2910	14.51 .3288
.071																				41.10 .0268	39.08 .0303	37.47 .0351	33.99 .0486	30.92 .0641	28.37 .0816	26.16 .1016	24.27 .1236	22.65 .1479	21.21 .1743	19.95 .2028	18.80 .2332	17.79 .2660	16.90 .3012
.075																					45.08 .0278	43.08 .0312	38.99 .0433	35.59 .0576	32.72 .0739	30.19 .0921	28.03 .1123	26.04 .1346	24.43 .1584	23.04 .1851	21.74 .2133	20.57 .2434	19.52 .2758
.080																						51.31 .0274	46.39 .0382	42.54 .0513	39.04 .0668	36.18 .0839	33.58 .1012	31.34 .1216	29.34 .1436	27.56 .1674	25.75 .1938	24.71 .2210	23.46 .2514
.085																							54.38 .0338	49.52 .0452	45.78 .0588	42.36 .0739	39.40 .0908	36.80 .1093	34.49 .1295	32.44 .1514	30.58 .1748	29.05 .2014	27.58 .2288
.090																							62.68 .0297	57.27 .0401	52.92 .0524	49.05 .0661	45.71 .0810	42.69 .0985	40.08 .1171	37.73 .1371	35.64 .1598	33.67 .1810	32.07 .2071
.095																								66.27 .0360	61.21 .0472	56.95 .0600	52.97 .0741	49.57 .0899	46.54 .1070	43.86 .1257	41.40 .1458	39.26 .1676	37.19 .1902
.100																								76.70 .0327	70.95 .0431	65.80 .0548	61.46 .0682	57.51 .0829	54.03 .0989	50.98 .1164	48.16 .1355	45.61 .1557	43.38 .1775
	.550	.600	.650	.700	.750	.800	.850	.900	.950	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7
.106	82.84 .0303	76.73 .0488	72.03 .0612	67.42 .0746	63.33 .0903	59.82 .1056	56.63 .1232	53.59 .1417	50.97 .1618	48.57 .1833	46.40 .2061	44.40 .2303	42.57 .2558	40.88 .2826	39.30 .3107	37.82 .3400	36.49 .3709	35.21 .4031	34.08 .4369	32.98 .4717	31.95 .5080	30.99 .5457	29.23 .6252	27.66 .7100	26.26 .8007	24.99 .8966	23.83 .9975	22.77 1.104	P f				
.112	P f	89.00 .0438	83.28 .0550	78.26 .0674	73.66 .0811	69.57 .0988	65.81 .1121	62.50 .1298	59.36 .1481	56.63 .1688	54.07 .1891	51.73 .2114	49.62 .2351	47.63 .2599	45.81 .2861	44.12 .3135	42.56 .3422	41.09 .3720	39.73 .4032	38.44 .4357	37.27 .4695	36.14 .5048	34.11 .5789	32.30 .6582	30.63 .7187	29.14 .8311	27.81 .9257	26.57 1.025	25.45 1.138	24.43 1.248			
.118		102.6 .0395	95.56 .0475	89.87 .0589	84.81 .0735	80.03 .0873	75.88 .1023	72.07 .1185	68.58 .1358	65.34 .1542	62.46 .1738	59.78 .1947	57.33 .2167	55.05 .2398	52.99 .2643	51.01 .2897	49.20 .3165	47.53 .3444	45.95 .3734	44.45 .4034	43.09 .4350	41.82 .4680	39.42 .5367	37.31 .6106	35.45 .6897	33.72 .7728	32.16 .8611	30.76 .9601	29.46 1.057	28.27 1.155	27.16 1.262			
.125			111.8 .0442	104.7 .0544	99.07 .0688	93.80 .0783	88.86 .0924	84.33 .1072	80.31 .1231	76.66 .1402	73.24 .1583	70.19 .1776	67.22 .1977	64.58 .2191	62.19 .2418	59.91 .2654	57.81 .2902	55.79 .3157	53.97 .3428	52.23 .3708	50.62 .4000	49.13 .4305	46.34 .4943	43.85 .5626	41.64 .6350	39.63 .7134	37.80 .7952	36.14 .8818	34.61 .9724	33.21 1.068	31.93 1.168	30.70 1.271			
.130			123.7 .0486	116.0 .0602	109.4 .0624	104.0 .0730	98.68 .0860	93.67 .0998	89.24 .1149	85.14 .1309	81.38 .1478	77.96 .1661	74.76 .1852	71.81 .2054	69.13 .2268	66.63 .2492	64.34 .2728	62.08 .2980	60.04 .3224	58.16 .3493	56.36 .3767	54.63 .4052	51.52 .4655	48.78 .5304	46.32 .5996	44.08 .6730	42.07 .7510	40.22 .8330	38.40 .9196	36.99 1.010	35.56 1.105	34.21 1.204	32.97 1.307		
.138				138.1 .0451	130.0 .0549	123.0 .0656	117.0 .0778	111.6 .0909	105.9 .1045	101.4 .1197	96.96 .1355	92.82 .1522	89.19 .1703	85.56 .1900	82.40 .2097	79.39 .2295	76.64 .2514	74.11 .2744	71.66 .2981	69.39 .3230	67.22 .3496	65.21 .3754	61.52 .4319	58.23 .4925	55.27 .5571	52.64 .6260	50.23 .6988	48.05 .7761	45.99 .8584	44.17 .9417	42.45 1.031	40.88 1.124	39.40 1.220			
.146					181.4 .0489	142.6 .0585	135.9 .0696	129.7 .0816	123.5 .0942	118.1 .1088	112.9 .1224	108.5 .1382	104.1 .1546	99.99 .1718	96.34 .1902	92.87 .2094	89.61 .2295	86.63 .2507	83.81 .2727	81.13 .2955	78.58 .3191	76.28 .3441	72.00 .3965	68.18 .4527	64.70 .5123	61.59 .5760	58.76 .6433	56.20 .7146	53.84 .7895	51.85 .8685	49.67 .9507	47.82 1.037	46.17 1.127			
.134						165.0 .0527	156.8 .0627	149.2 .0734	142.7 .0853	136.6 .0981	130.7 .1115	125.3 .1258	120.0 .1405	115.7 .1570	111.6 .1741	107.6 .1920	103.8 .2105	100.3 .2300	97.07 .2505	94.03 .2718	91.13 .2939	88.44 .3170	83.44 .3655	78.99 .4172	75.06 .4736	71.37 .5323	68.13 .5952	65.15 .6615	62.46 .7318	59.95 .8052	57.65 .8825	55.50 .9629	53.52 1.047			
.162							179.4 .0565	170.3 .0662	162.7 .0771	156.3 .0890	149.8 .1015	143.5 .1147	136.7 .1288	134.4 .1448	128.0 .1595	124.7 .1762	119.3 .1935	116.2 .2117	111.6 .2307	108.9 .2505	104.8 .2713	102.4 .2925	96.66 .3381	91.44 .3865	86.75 .4382	82.59 .4926	78.80 .5522	75.31 .5991	72.16 .6783	69.30 .7483	66.56 .8197	64.11 .8954	61.90 .9728
.170							203.6 .0511	194.5 .0684	185.0 .0780	177.1 .0888	170.5 .0927	163.5 .1049	157.1 .1180	151.3 .1319	145.9 .1466	140.9 .1622	136.1 .1785	131.6 .1954	127.4 .2132	123.4 .2324	119.5 .2505	116.1 .2709	109.6 .3133	103.9 .3589	98.56 .4072	93.84 .4580	89.60 .5140	85.65 .5716	82.06 .6327	78.81 .6973	75.77 .7647	72.91 .8347	70.25 .9068
.180								225.9 .0535	215.5 .0625	206.1 .0722	198.1 .0828	190.3 .0941	183.6 .1086	176.8 .1191	170.4 .1325	164.5 .1467	159.1 .1618	153.9 .1774	149.0 .1938	144.3 .2108	140.0 .2286	135.7 .2468	128.3 .2861	121.5 .3281	115.6 .3734	110.0 .4210	105.0 .4710	100.3 .5250	96.19 .5819	92.35 .6415	88.77 .7038	85.48 .7682	82.46 .8370
.187									241.1 .0587	230.2 .0674	220.4 .0772	212.1 .0888	205.1 .0999	197.4 .1119	190.4 .1247	183.7 .1381	177.6 .1523	171.8 .1672	166.7 .1831	161.6 .1995	156.6 .2162	152.1 .2339	143.6 .2711	136.2 .3116	129.5 .3548	123.2 .4002	117.5 .4486	112.4 .4998	107.7 .5541	103.4 .6111	99.48 .6711	95.79 .7337	92.31 .7987
.207											292.8 .0637	281.2 .0727	269.8 .0822	261.5 .0930	252.0 .1030	244.2 .1158	234.8 .1280	228.3 .1480	221.4 .1654	214.9 .1887	208.4 .1833	202.7 .1990	191.5 .2376	181.6 .2805	172.6 .3041	164.5 .3443	157.2 .3871	150.3 .4321	144.0 .4794	138.3 .5296	133.0 .5820	128.1 .6373	123.5 .6948

*Decimal Equivalent For Music Wire Gauge

...E OF MUSIC WIRE AND STAINLESS STEEL

SIDE DIAMETER OF SPRING — PREFERRED NUMBERS												BASIC STRESS (S) X 10^{-3}	FORMULAS $P \times DR_1$	FORMULAS $\frac{f \times R_1}{D^3}$	WIRE DIAM. *d
1.200	1.250	1.300	1.400	1.500	1.600	1.700	1.800	1.900	2.000	2.100					
												151.	.0304	4.941	.008
												150.	.0429	4.363	.009
												150.	.0589	3.927	.010
												149.	.0779	3.546	.011
												149.	.1011	3.251	.012
												148.	.1277	2.980	.013
												147.	.1584	2.749	.014
												146.	.2348	2.389	.016
												145.	.3321	2.109	.018
												144.	.4524	1.885	.020
												143.	.5981	1.702	.022
												142.	.7706	1.549	.024
												141.	.9734	1.420	.026
												139.	1.331	1.255	.029
												137.	1.603	1.157	.031
												136.	1.920	1.079	.033
												135.	2.273	1.010	.035
												134.	2.665	.9481	.037
												133.	3.098	.8928	.039
												132.	3.573	.8429	.041
												130.	4.059	.7915	.043
												129.	4.617	.7505	.045
												128.	5.218	.7130	.047
												127.	5.865	.6785	.049
												126.	6.566	.6468	.051
												124.	8.103	.5902	.055
8.056 .8086	7.739 .7186											122.	9.835	.5413	.059
9.629 .8041	9.249 .6882	8.908 .7197										121.	11.78	.5028	.063
11.56 .5963	11.11 .6887	10.70 .6637	9.953 .7001									120.	14.17	.4689	.067
13.50 .5899	12.99 .5585	12.49 .6885	11.63 .7162	10.83 .8796								118.	16.58	.4351	.071
15.61 .4085	15.00 .5129	14.45 .5800	13.45 .6594	12.58 .7670	11.81 .8825							116.	19.21	.4049	.075
18.73 .4283	18.01 .4806	17.35 .5129	16.16 .6049	15.10 .7038	14.15 .8087							115.	23.12	.3763	.080
22.04 .3981	21.19 .4278	20.41 .4674	19.01 .5521	17.78 .6434	16.70 .7416	15.74 .8467	14.89 .9583					113.	27.25	.3480	.085
25.62 .3562	24.65 .3911	23.74 .4274	22.11 .5051	20.67 .5890	19.43 .6790	18.32 .7771	17.33 .8810	16.45 .9914				111.	31.77	.3229	.090
29.82 .3263	28.66 .3613	27.62 .3954	25.71 .4678	24.05 .5459	22.62 .6310	21.33 .7216	20.19 .8189	19.14 .9212	18.22 1.031			110.	37.04	.3031	.095
34.69 .3078	33.36 .3303	32.14 .3703	29.94 .4305	28.00 .5122	26.33 .5923	24.84 .6783	23.49 .7692	22.30 .8672	21.21 .9659	20.22 1.079		110.	43.20	.2880	.100
3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2					
												109.	50.98	.2692	.106
												108.	59.59	.2525	.112
												107.	69.04	.2374	.118
												106.	81.30	.2220	.125
												105.	90.59	.2115	.130
												105.	108.4	.1997	.138
												104.	127.1	.1865	.146
45.36 1.589	44.04 1.626											103.8	147.7	.1751	.154
52.42 1.418	50.88 1.517	49.40 1.618										102.	170.3	.1648	.162
59.72 1.326	57.98 1.418	56.29 1.513	54.75 1.613	53.25 1.716								101.	194.9	.1555	.170
70.02 1.224	67.96 1.311	66.03 1.400	64.22 1.492	62.46 1.586	60.80 1.684	59.29 1.786						100.	229.0	.1454	.180
70.41 1.168	76.17 1.253	74.00 1.338	71.82 1.425	69.99 1.517	68.13 1.618	66.36 1.726	64.76 1.837	63.18 1.949				100.	256.8	.1400	.187
104.9 1.021	101.8 1.094	98.98 1.170	96.24 1.248	93.66 1.328	91.23 1.412	88.94 1.498	86.69 1.585	84.56 1.676	82.54 1.768	80.63 1.864		99.	344.8	.1252	.207

provide a spring whose ends will have this specific relationship. Thus the number of coils must be modified by some fraction to provide the desired relative position of ends. Here a whole number of coils is chosen to provide hooks facing in the same direction. To maintain the required gradient, the coil diameter of the spring is modified by the equation in Step 7.

The "free length," H, of an entension spring is the length of the spring unloaded, measured inside the hooks at the ends of the spring (see Fig. 1). Table III gives length limits for types of hooks in terms of coil I.D. Since free length is not important in itself for most extension spring applications, it is often specified as an approximate value permitting the spring manufacturer to vary it to suit the more important test load specification.

It is most important to understand that the free length must not be too great or too small for the required initial length, L_1. If the required initial length does not fall within limits expressed in Step 11, several alternatives remain:

- Reorient assembly components to adjust the requirement
- Select special hook (see Table III, examples 5-10)
- Try reduced hooks, beginning with Step 3, eliminating

CLOSE-WOUND EXTENSION (Random Hook Angles)	$\Delta H \pm \frac{K}{100}\sqrt{X \cdot W}$
CLOSE-WOUND EXTENSION (Specified Hook Angles)	$\Delta H \pm \frac{K}{100}\sqrt{X \cdot Y}$

Wire Dia. d	X Music Wire & Stainless
.008	48
.009	42
.010	36
.011	32
.012	28
.013	26
.014	24
.016	20
.018	17
.020	15
.022	13
.023	
.024	12
.025	
.026	11
.029	9
.031	9
.032	
.033	8
.035	7
.036	
.037	7
.039	6
.040	
.041	6
.043	6
.045	5
.047	5
.049	5
.051	5
.054	
.055	4
.057	
.059	4
.063	3.5
.064	
.067	3.3
.071	3.0
.072	
.075	2.8
.080	2.6
.085	2.4
.090	2.2
.091	
.093	
.095	2.1
.100	2.0
.102	
.106	1.8

Wire Dia. d	X Music Wire & Stainless
.112	1.7
.114	
.118	1.6
.120	
.125	1.5
.128	
.130	1.4
.135	
.138	1.3
.144	
.146	1.2
.148	
.154	1.1
.156	
.162	1.1
.170	1.0
.177	
.180	0.9
.182	
.187	0.9
.192	
.204	
.207	0.8

Index $\frac{D}{d}$	Y	W
3	4	1.8
3.5	4.5	2.1
4	5	2.3
4.5	6	2.7
5	6.5	2.9
5.5	7	3.2
6	8	3.5
6.5	9	4
7	9	4
7.5	10	4.5
8	11	5
8.5	11	5
9	12	5.5
9.5	13	5.5
10	13	6
10.5	14	6
11	15	6.5
11.5	15	7
12	16	7
12.5	17	7
13	17	8
13.5	18	8
14	19	8
14.5	19	9
15	20	9
16	21	9
17	23	10
18	24	11
19	25	11
20	27	12

Table IV—Calculational data for determining manufacturing variations in gradient and in load at length.

DESIGN TIME SAVER

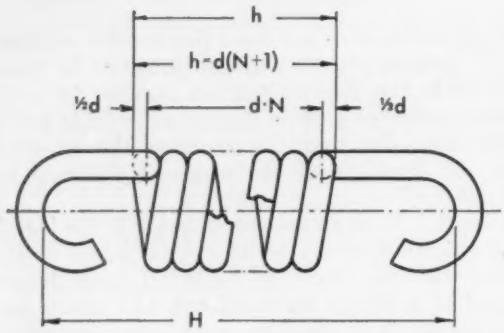


Fig. 1

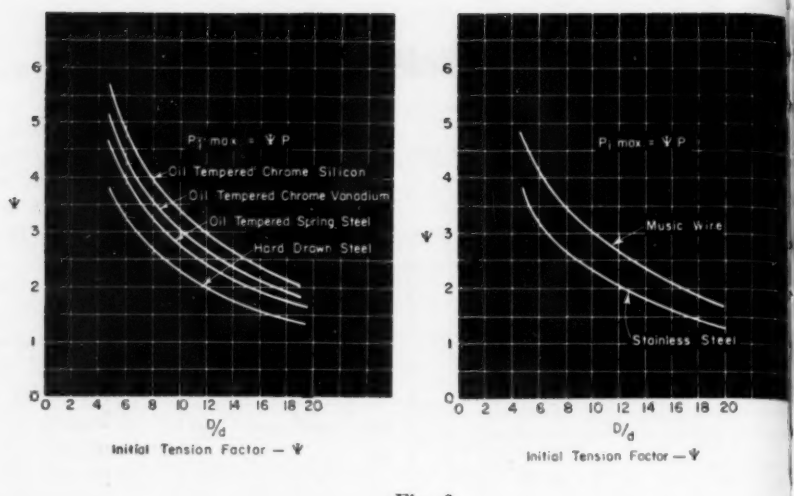


Fig. 2

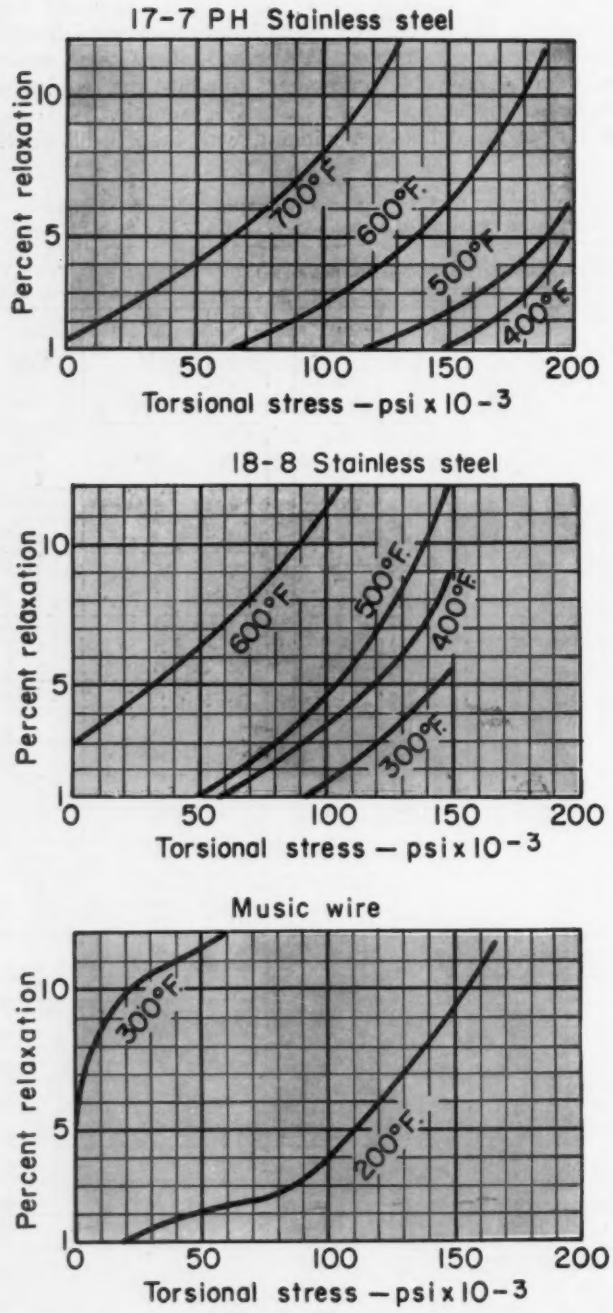


Fig. 6—Effect of elevated temperatures on helical springs.

the factor 1.3 (if L_1 is too great).

If the relation of load, length and gradient leads to a spring whose initial tension does not fall within the limits expressed in Step 13, the most practical method of adjustment would be through changing the required P_1 or L_1 through the steps suggested for Step 11. The expression $h \cdot k \cdot \Delta i$ represents initial tension variation, ΔP_1. Initial tension, P_1, must be great enough that its possible variation will not prevent the weakest spring in the lot from being close-wound. The factor Ψ introduces the practical maximum limit on initial tension for various values of spring index and is obtained from Figure 2. These Ψ curves represent the results of controlled experimentation.

III. STRESS

If properly followed, the design procedure takes all stresses into account, preventing design for operation at unsafe stresses unless one of the following conditions is encountered:

Though properly designed for its service requirements a tension spring may, in handling or assembly, have to be stressed beyond its "final stress" (S_2). For this reason, in cases where you anticipate such handling, it is wise to calculate the ultimate stress, S′, that may be encountered at the extreme length, L′. Use the relation

$$S' = S_2 + K(L'-L_2)S/P$$

to ascertain that S′ does not exceed 0.6 S_y.

The values for S_y read from the graph in Fig. 5 apply only to compression springs which can be cold-set to induce these apparent elastic limits. The true elastic limit of the material, before residual stresses are induced by setting, is about 60 percent of the values shown in the graph—hence the factor 0.6 in the stress check point.

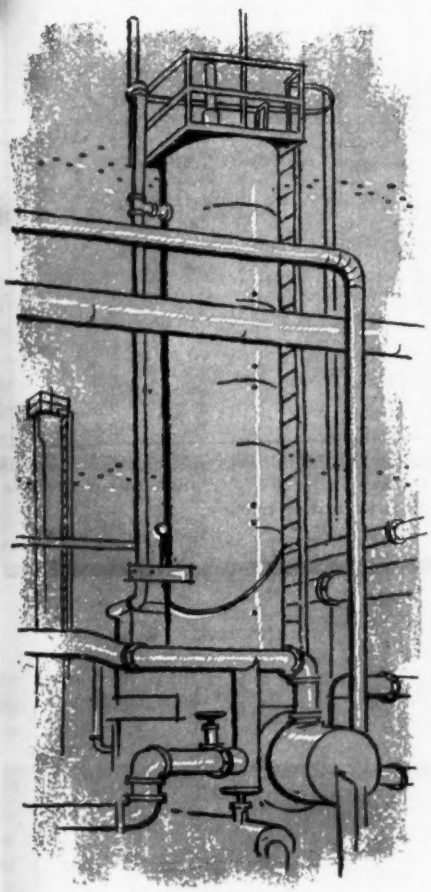
When temperature exceeds normal indoor temperature, then a danger of permanent relaxation might exist, and the amount of this relaxation should be determined from the data in Fig. 6. If the predicted relaxation is not tolerable, then a spring of higher equivalent load P should be selected from the chart to reduce the stress and thus reduce the amount of relaxation.

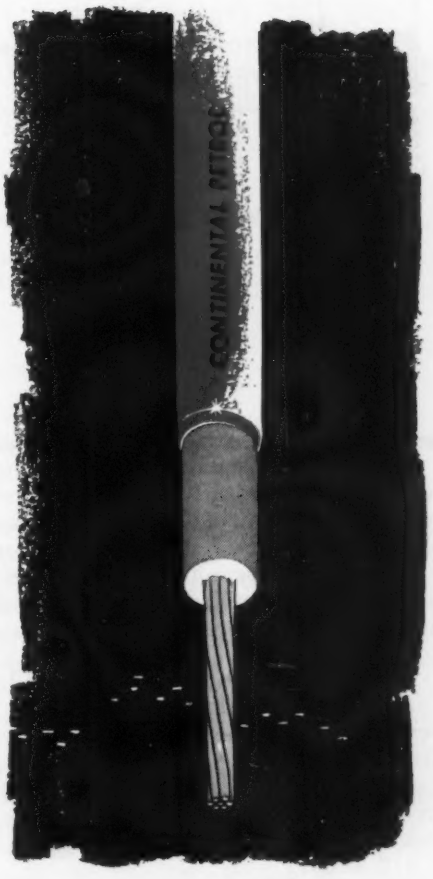
IV. VARIATIONS AND LIMITS

Of course, tolerances must be bilateral, allowing a variation both above and below the nominal value used in the calculation. Otherwise a contradictory specification will result and must be reconciled before the spring manu-

now! *a low cost gasoline/oil resistant insulated wire . . . the NEW Nylon-jacketed*

CONTINENTAL *PETROL* WIRE





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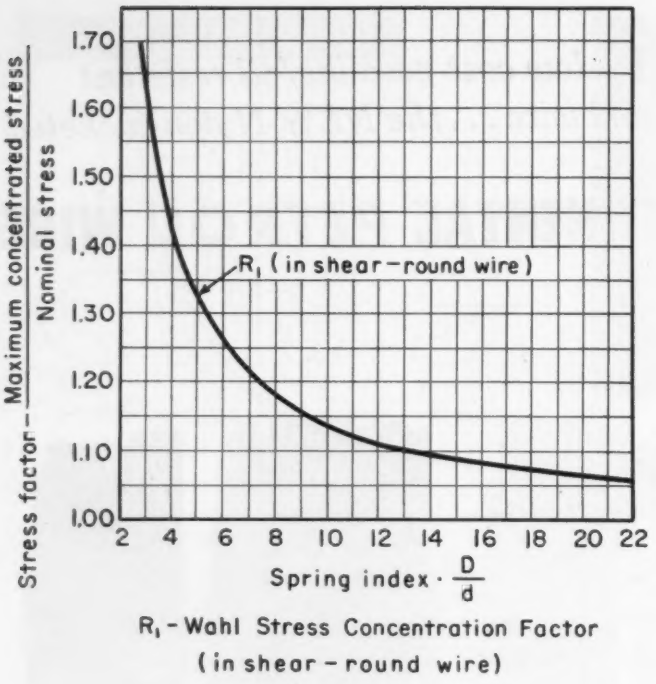

Fig. 3

facturer can proceed with a production quantity.

The normal manufacturing variation ΔD from Fig. 7 represents the process capability. Normally over-all tolerance of 1.6ΔD should be allowed in specifying maximum O.D. and minimum I.D. of extension springs (Steps 2 and 3). This figure permits gradient centering in the manufacturing process without change of spring length. This is necessary when the actual wire size is near the upper or lower limit.

Free length variation, ΔH, is caused by variation in wire size and variation in length of hooks. A variation of 1 percent in wire size is an approximation of the tolerance demanded by spring wire manufacturers. Variation in the length of hooks is caused by coil diameter variation, D, as well as spring positioning and tool wear. An acceptable tolerance for hook variation is 2ΔD (but not less than ±.015 inch).

Thus in calculating free length variation in Step 4 the following formula can be used:

$\Delta H = .01h + 2\Delta D$ (where 2ΔD is never less than .015 inch) or, as a fast practical calculation:

$\Delta H = .02H$

However, since free length in itself is not an important requirement for most extension spring applications, it is often specified as an approximate value. This permits the spring manufacturer to vary it to suit the more important test load specification.

Gradient variation (Step 5) of close-wound extension springs can be calculated from the formulas and factors as presented in Table IV. (Figures for X for carbon and alloy steel wire are found in the compression spring article.) Gradient variation is not often critical. However, the same means as described for compression springs for improving upon the indicated limits are available at higher cost.

The formulas for initial and final load variations ΔP_1 and ΔP_2 are based on the known capabilities of spring-winding machinery, but can be improved, at additional cost, through 100 percent inspection and segregation or corrective operations.

Like other components of a spring, the hooks or ends of

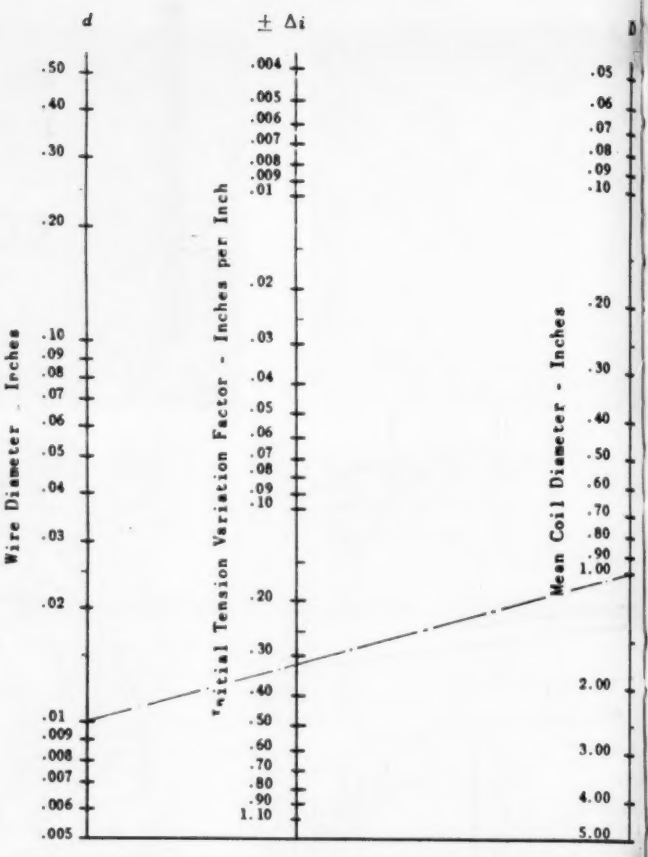

Fig. 4—Nomograph for determining △P1, manufacturing variation in initial tension.

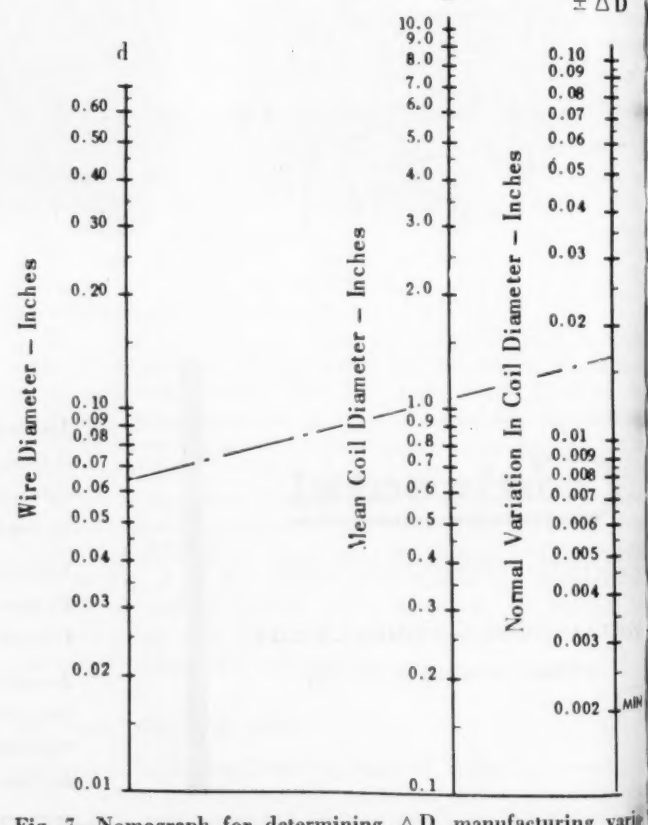

Fig. 7—Nomograph for determining △D, manufacturing variation in coil diameter.

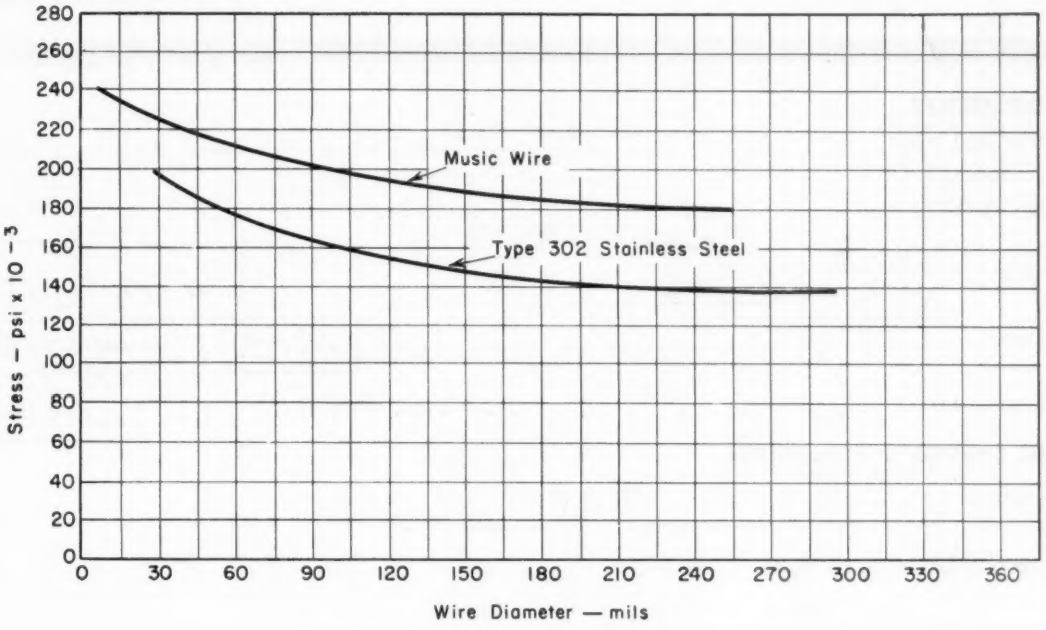

Fig. 5—Maximum apparent elastic limit, S_y. Music wire and stainless steel.

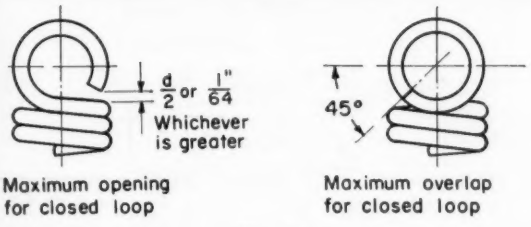

Fig. 8

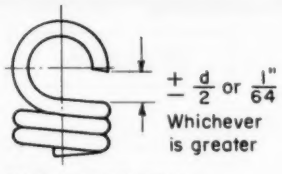

Fig. 9

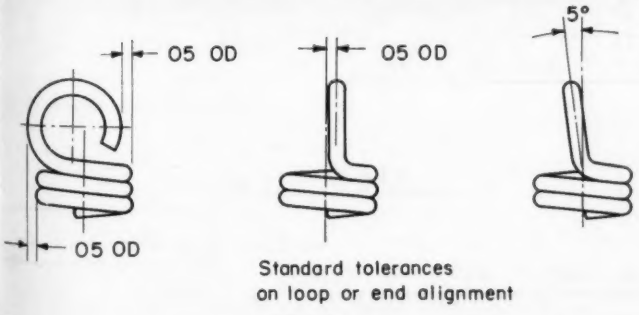

Fig. 10

extension springs will vary from one to another in any production lot. Manifestations of such variances are too much or too little wire in a closed loop, dimensional variance in specified hook openings, misalignment, and variance in the angular relationship between loops or hooks. These variations are traceable to such factors as variation in the "springback" of material, wire diameter variation and variation in positioning during the looping operation.

For many applications, it doesn't particularly matter if extension spring hooks or ends do vary in dimensions. Sometimes, however, it does—particularly when the spring is to be used in delicate instruments. Tolerances for hook dimensions are shown in Figs. 8, 9 and 10. Process capability in angular variation between ends is figured as 120 ($\Delta D/D$) N.

Most applications permit a variation of 45 degrees. Closer tolerances than this should only be specified when absolutely necessary. If the expression gives a variation exceeding 90 degrees, then "random angle" should be considered for the tolerance to be specified. It is important to note that unless otherwise specified, the angular relationship of loops will be measured with the spring extended on a free turning attachment to the minimum length that will cause separation of all active coils.

Should tolerances be less than those outlined above it would be well to consult with the spring manufacturer. Certainly "random angle" should be clearly specified wherever the application permits. Operations added to improve relative hook position add appreciably to the cost

A step by step Design Procedure Work Sheet is on page 90-91. End

For one free reprint of both articles for your design file, circle No. 163 on the Reader Inquiry card.

I. REQUIREMENTS

1. Initial load, P_1 . . . . . 6.0 lbs.
2. Final load, P_2 . . . . . 9.5 lbs.
3. Gradient, $K = \frac{P_2 - P_1}{F} = \frac{3.5}{2.5}$ . . . . . 1.4 lb./in.
4. Material . . . . . 18-8 STAINLESS (Type 302)
5. Minimum life . . . . . 10,000 cycles

II. BASIC SPRING CALCULATION

1. Stress ratio, $S_r = \frac{P_2 - P_1}{P_2} =$ 0.37
2. Correction factor, A (Table I) 87
3. Corrected load, $P_t = \frac{1.3P_2}{A} =$ 14.2 lb.
   (1.3 multiplier applies when hook diameter equals body diameter)
4. Tabulated values (See Spring Charts,)
   a. Outside diameter, OD' . . . . . .650 in.
   b. Chart Load, P . . . . . 14.55 lbs.
   c. Deflection per coil, f 1653
   d. Wire diameter, d . . . . . .059 in.
   e. Basic stress, S . . . . . 122,000 psi
   Note: If elevated temperature, check steps 2 to 4 under "Stress" before proceeding.
   f. Modulus correction, U 0.833
5. Number of active coils, $N' = \frac{P}{fK} U =$ 52.4
   a. Specified number of coils, N, adjusted for relative position of ends 52
6. Body length (Fig. 1), $h = d\ (N + 1) =$ 3.13 in.
7. Mean coil diameter, $D = (OD' - d) \sqrt[3]{\frac{N'}{N}}$ $.591\sqrt[3]{\frac{52.4}{52}} = .592$ in.
8. Free length, $H = h +$ length of hooks $=$ 3.13+1.066=4.196 in.
9. Spring index, $\frac{D}{d} =$ 10.
10. Initial tension variation factor, Δ_i (Fig. 4) . . . . . $=$ .066 in./in.
11. Initial length, L_1, required by application . . . . . 6.5 in.

CHECK POINT L_1 { ✓ is not less than $H + h\Delta_i =$ 4.196+.207=4.403 ; ✓ is not greater than $H + \frac{P_1}{K} - h\Delta_i =$ 8.269

12. Final length, $L_2 = L_1 + \frac{P_2 - P_1}{K} = 6.5 + \frac{9.5 - 6.0}{1.4} = \ldots$ **9.0** in.

13. Initial tension

a. Initial tension, $P_i = P_1 - K(L_1 - H) =$ **2.78** lbs.

b. Initial tension factor, Ψ (Fig. 2) **0.23**

CHECK POINT — P_i ✓ is not less than $hK\Delta_i$ **.290**; ✓ is not greater than $P\Psi$ **3.35**

II. STRESS

1. Wahl Stress Concentration Factor, R_1 (Fig. 3) **1.13**

2. Torsional Stress in Coils, $S_2 = \frac{S}{R_1} \times \frac{P_2}{P} =$ **70,500** psi.

CHECK POINT — S_y (Fig. 5) . . . . . = **180,000** psi

S_2 must not be greater than .6 S_y.

Note: If maximum extended length exceeds L_2, see instructions.

3. Operating Temperature . . . . . = **450°F**

4. Per cent relaxation at elevated temperature (Fig. 6) = ... **1.7** %

IV. VARIATIONS AND LIMITS

1. Coil diameter variation, ΔD (Fig. 7) . . . . . **.007** in.

2. Maximum outside diameter, $OD_{max.} \geq (D + d) + 1.6\Delta D = .651 + 1.6(.007)$ . . . **.662** in.

3. Minimum inside diameter, $ID_{min.} \leq (D - d) - 1.6\Delta D = .533 - 1.6(.007)$ . . . . **.522** in.

4. Free length variation, $\Delta H = .02H$ . . . . . **± .084** in.

5. Gradient variation, $\Delta K = \frac{K}{100}\sqrt{X + Y}$ or $\frac{K}{100}\sqrt{X + W}$ (from Table IV) **± .058** lb./in.

6. Initial load variation,

$$\Delta P_1 = \frac{P_1 - P_i}{100}\sqrt{\left(\frac{\Delta K}{K} \times 100\right)^2 + \left(\frac{.02H}{L_1 - H} \times 100\right)^2 + \left(\frac{h\Delta_i}{L_1 - H} \times 100\right)^2} \quad \ldots\ldots$$ **± .339** lb.

7. Final load variation,

$$\Delta P_2 = \frac{P_2 - P_i}{100}\sqrt{\left(\frac{\Delta K}{K} \times 100\right)^2 + \left(\frac{.02H}{L_2 - H} \times 100\right)^2 + \left(\frac{h\Delta_i}{L_2 - H} \times 100\right)^2} \quad \ldots\ldots$$ **± .418** lb.

8. End relationship variation

$\Delta N = 120\frac{\Delta D}{D} \times N$ or 45°, whichever is greater $= 120\frac{(.007)}{.592} \times 52 = \ldots$ **± 74** deg.

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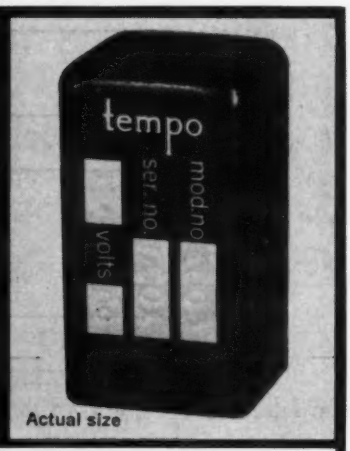

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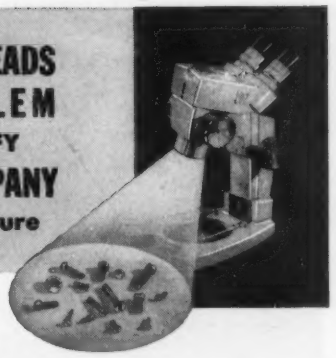

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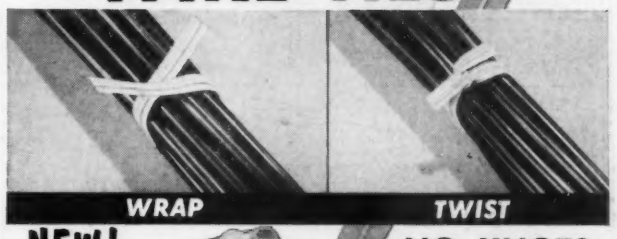

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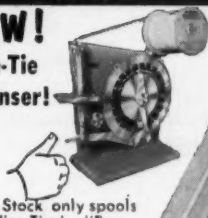

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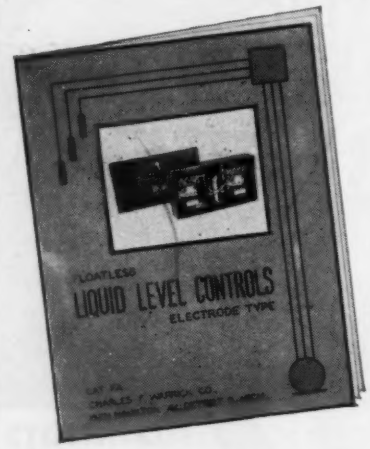

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New Looks At An Old Technique

The imaginative scientist who dares to strike out into new avenues and to depart from the old and well-trodden path is bound to be just as suspect by his contemporaries as the social or political thinker of equal daring. There is in all of us, in the technical as well as the non-technical, a fear of the unexplored. It is unfortunate and often costly that this mental inertia bogs down many a development and oftentimes saddles the brain with vast projects for perfecting the old without as much as leaving the slightest possibility for even a pintsized breakthrough to new concepts.

There is a vital field of electromechanics in our life—that of generation of electricity by taking power from a rotating shaft. The exact requirements of the loads of a modern industrial plant or a missile or electronically controlled plane demand a voltage and frequency stabilization independent of shaft rotation. It is evident that a more accurately machined stator or better wound coil will not cope with the essential problem of control.

In a paper presented before the SAE Aeronautical Meeting in Los Angeles last month, Karl Martinez, Chief Acoustics-Electrical Research at Boeing, puts his finger on this mental inertia that prevents the synthesizing of electric systems producing constant frequency without using constant speed drives, and keeps the door closed to newer systems to replace the present ones—systems that will be more reliable, simpler, have less maintenance, cost less and meet the challenges of today.

From the first rotation of a copper disc between the poles of a horseshoe magnet by Faraday in 1831, through the days of Pucinotti and Gramme with their ring winding and Van Depoeles' carbon brushes and the first generation of alternating current by Zipernowski and others to the induction motor of Nicola Tesla we have witnessed a steady stream of bigger and better, but never different ways of producing the adrenaline of modern society—electricity. Martinez points the way to many possibilities, although the qualification is there that they are all based on future state-of-the-art development. Here are a few of these:

- A system is being constructed experimentally in England whereby a variable speed input delivers constant voltage and frequency. It is based on the use of two wound-rotor induction generators mounted on the same shaft. Two stators connected in series supply power to the electric system. The two rotors are connected in parallel. A phase angle shift is produced between the magnetic fields of the two machines by mechanically shifting one stator with respect to the other. Excitation and voltage control are

Continued on page 9

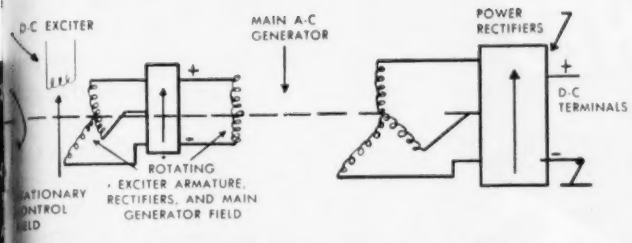

Fig. 1—A practical brushless d-c generator feasible with future state-of-art development can be built with present-day components. A brushless alternator feeds power to silicon rectifiers which deliver direct current at output terminals. Installing the power rectifiers in the generator housing simplifies cooling and will probably save weight. More than three phases may be preferable to reduce the size of the rectifier cells or to reduce the output ripple voltage. An output voltage of 120 volts is suggested. Rectifiers are available that will withstand a back voltage of 150 volts so it would be necessary to limit peak overvoltage on the system to 125 percent.

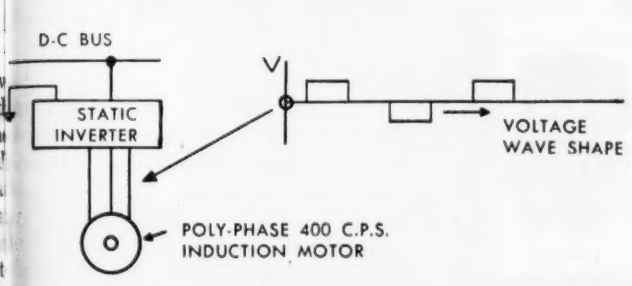

Fig. 2—Scheme for a brushless "d-c" motor and input voltage would consist of a static inverter and a polyphase induction motor. The d-c power is converted to polyphase power to drive the induction motor. It appears a flat-top voltage wave as indicated on the diagram would permit power transistors in the inverter to operate efficiently as "on-off" switches and also give satisfactory motor efficiency. Harmonic currents from the non-sinusoidal voltage wave can be minimized by chording the winding, selecting the number of slots, and skewing the stator or rotor punching. Other than procurement of the high power transistors there appears to be no major problems. Weight reduction of the inverter portion of the motor over that of present-day units probably can be accomplished by omitting output transformer; using a flat-top voltage wave eliminating filters required for a sinusoidal wave; mounting the power transistors in the motor to save hardware and simplify cooling.

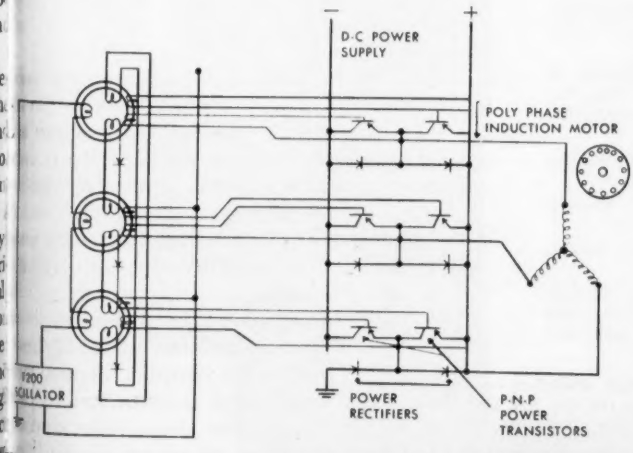

Fig. 3—Complete circuit diagram for brushless motor. Interesting features of the scheme are the timing circuit for power transistors and the use of rectifiers to carry the lagging load current. Frequency is controlled by the 1200 cps oscillator. Phase displacement between the phase voltages is obtained by use of a ring-counter circuit proposed by Hollomore Electronic Co. for control of a static inverter.

...d on page 9

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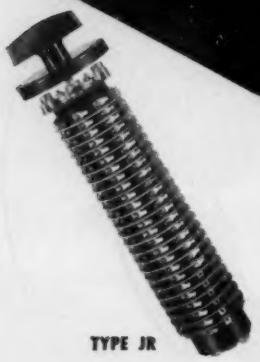
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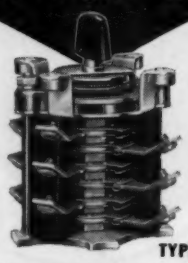
TYPE P

Gear-operated TYPE JR

TYPE A

TYPE AF

TYPE JD-JS

TYPE HT

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- **TYPE P** — Multi-section, up to 4 positions, snap-action, rating 10 amperes — 125 volts a-c, 5 amperes — 125 volts d-c, 30, 60, 100, 200 amperes at 500 volts a-c, or 250 volts d-c. Can be assembled to meet Specification MIL-S-15291.
- **TYPE JR** — up to 8 positions, 30 sections maximum, detent-action, rating 10 amperes at 125 volts a-c, 5 amperes 125 volts d-c.
- **TYPE JD-JS** — up to 8 positions, 5 sections maximum, detent-action or snap-action, rating 30 amperes at 230 volts a-c.
- **TYPE HT** — up to 16 positions, 6 sections maximum, detent-action, rating 5 amperes at 125 volts a-c.
- Bureau of Ships No. 9000-S6202-74085 rating 10 amperes at 120 volts a-c. BuShips 9000-S6202-74090, 9000-S6202-74096, and 9000-S6202-74224, ratings 30, 60, and 200 amperes, 500 volts a-c — 250 volts d-c.

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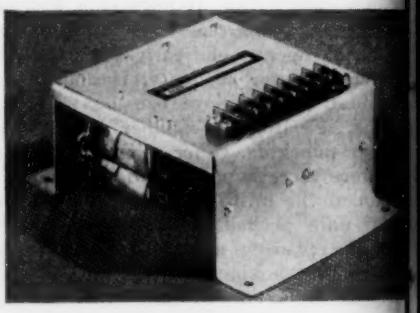
FOR MORE INFORMATION CIRCLE 79 ON INQUIRY CARD

provided by varying amounts of stat capacitors connected to the generat terminals through saturable controls.

• When high-current power transisto are developed several variations w be possible. Brushless generators a motors with static control componen would have the advantage of better r liability and less weight; operation generators in parallel would be simpl fied. The generator would simply be a alternator feeding power to rectifie delivering direct current a' the outp terminals. A brushless d-c motor coul consist of a static inverter and a pol phase induction motor. The d-c pow is converted to polyphase power drive the induction motor.

• A system consisting of magnetize compressor blades on a turbojet engi with the generator stator mounted the compressor frame.

And many more, each requiring breakaway from the proven and know But here again it seems that only wh imagination soars sky high are resul down to earth.



Over-Under Speed Control For Machine Tools

Magnetic-amplifier speed-control rela for low surface speeds is now avail able as a safety device for machine too builders. Designed for use with a mag netic pickup mounted near a rotati gear, this tubeless amplifier and rel operates either over or under a pres critical speed. The chassis fits in commercially available wiring bo Gear teeth passing the pickup at 0.0 inches spacing and travelling 40 to 5 inches per second peripheral speed pr vide a signal that is amplified by t device to provide single pole doubl throw switching of electrical loads u to 5 amp non-inductive. Critical spee for the relay is set by adjusting spacin between the magnetic pickup and a tuating metal. Electro Products Labo atories, Inc., Chicago 40, Ill.

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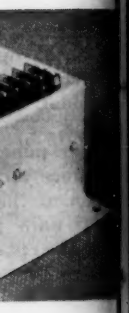

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